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VOLUME 7

1913

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ON TWO MUSCLE ANOMALIES OF THE LOWER EXTREMITY

J. PARSONS SCHAEFFER

Yale University

From the Anatomical Laboratory of the Yale Medical School

TWO FIGURES

The anomalous muscles described and figured in this brief note were encountered, among others, in the Anatomical Laboratory of the Yale Medical School, during the session of 1911–12.

The muscles to be considered are (A) an *anomalous sartorius* (fig. 1) and (B) a well differentiated and developed *tensor fasciae suralis* (fig. 2). Since both of the anomalies are of rather infrequent occurrence a descriptive note on the anatomy of the muscles may not be amiss at this time.

A. AN ANOMALOUS MUSCULUS SARTORIUS

It is well known that the sartorius muscle is occasionally wholly or partially duplicated. Cases have also been reported in which the muscle was rendered digastric by an intervening tendon, or merely crossed by a tendinous inscription. The muscle also varies in its origin and insertion, and it is very rarely entirely absent. The anomalies and comparative anatomy of this muscle are fully considered by Dr. LeDouble in his 'Traité des Variations du Système musculaire de l'Homme,' to which the reader is referred.

The anomalous sartorius muscle in question was found on the left side of a white, male cadaver, aged approximately sixty-five years. The muscle was duplicated for a goodly portion of its course and incidentally it had two heads of origin (fig. 1).

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The *lateral head* of the anomalous muscle represented the normal sartorius in every respect; arising, as is usual for the normal muscle, from the anterior superior spine of the os ilium and from the area of the latter immediately caudal to its anterior superior spine. After taking the usual course of the normal muscle and uniting with the medial or anomalous head, the combined heads inserted on the medial surface of the tibia near its tuberosity and into the neighboring deep fascia of the leg (fig. 1).

The *medial or anomalous head* arose by means of a very narrow but distinct tendon from the eminentia iliopectinea, just medial to the psoas major muscle and the external iliac vein. The tendinous head of origin at once passed dorsal to the external iliac vein, and after reaching a point immediately distal to the inguinal ligament of Poupart the tendon passed dorsal and between the femoral artery and the femoral vein, here resting on the iliopsoas muscle. The medial head then deviated lateralward and passed between the femoral and profunda femoral arteries, i.e., the head was ventral to the latter vessel and dorsal to the former. The medial head here was just distal to the point of origin of the profunda femoral (fig. 1).

The medial head now became fleshy and coursed ventral to some of the branches of the femoral (anterior crural) nerve, and from here took a course more or less parallel to the lateral head of the sartorius, and at a plane ventral to the femoral artery and the vastus medialis muscle.

At a point 17 cm. from the insertion of the anomalous sartorius muscle its medial and lateral heads joined, and from here the two heads coursed as a single muscle to the usual point of insertion of the normal sartorius (fig. 1).

The fleshy portion of the medial head was 24 cm. long and the tendinous portion measured about 7 cm. in length. The fleshy portion of the medial head had a more or less uniform breadth of 4 mm. and the tendinous portion measured uniformly slightly less than 1 mm. in breadth.

Both heads of the muscle were supplied by branches from the femoral (anterior crural) nerve.

B. MUSCULUS TENSOR FACIAE SURALIS

Supernumerary muscles of the dorsum of the thigh and calf of various dispositions and types have been observed and reported by a number of anatomists; however the cases in which additional muscles appear in the thigh and sural regions are not very common. Gruber, Halliburton, Kelch, LeDouble, Testut, Turner, and others have observed supernumerary muscles of these regions.

One-bellied supernumerary muscles arising from the biceps femoris muscle and inserting into the tendo calcaneus (Achillis) have been described by Kelch, Gruber, Turner, and others. Halliburton observed a 'supernumerary two-bellied slip of the biceps being continued into the gastrocnemius.' Gruber reported a similar case of a digastric supernumerary muscular slip which arose from the long head of the biceps femoris muscle and inserted into the tendo calcaneus (Achillis), and another one-bellied slip which also arose from the long head of the biceps femoris but which inserted into the fascia suralis. Turner and Gruber reported muscular slips with similar insertions into the fascia suralis but the origin of those slips was from the semitendinosus muscle. Turner

> also saw, ... a m. tensor fasciae poplitealis . . . . which arose by two heads; one, a broad, thin band of muscle arose from the linea aspera, between the origins of the short head of the biceps and the vastus externus, and the fibers of which passed directly backwards; the other arose from the long tendon of the biceps, 4 inches below the ischial tuber, and passed down the back of the thigh to join the other head, and to be inserted along with it into the deep surface of the fascia at the upper angle of the popliteal space.

The reader is referred to the writings of Gruber, LeDouble, and Testut for a fuller consideration of the supernumerary muscles of these regions.

The supernumerary muscle—the subject of this note—was found on the right side of a male cadaver, aged sixty-four years. The muscle obviously tensed the sural fascia when in action and doubtless should be classed as a 'tensor fasciae suralis muscle.'

Its anatomy fit fairly well the description given by Wenzel Gruber for a supernumerary muscle of this region observed by him.

The tensor fasciae suralis muscle in question (fig. 2) was well differentiated and strongly developed, more or less fusiform in shape, and about 5 inches in length. It arose by means of a distinct tendon which was more or less confluent with the tendon of the long head of the biceps femoris muscle. At its point of origin the accessory muscle was somewhat hidden by the overlying long head of the biceps femoris.

After arising from the latter, the tensor fasciae suralis soon became fleshy and took a direction more or less parallel to the long head of the biceps femoris muscle, and in its course bounded the popliteal space laterally.

The muscle again became tendinous and after an expansion of this tendon the muscle inserted into the sural fascia over the lateral head of the gastrocnemius muscle, just distal to the popliteal space (fig. 2). At the point of insertion of the tensor fasciae suralis muscle it more or less replaced the usual fibrous prolongations from the tendon of the biceps femoris muscle into the sural fascia.

The supernumerary muscle was supplied by a twig from the nerve to the long head of the biceps femoris muscle which was supplied by a branch from the great sciatic nerve (n. ischiadicus).

The cadavera in which the aforementioned anomalous muscles were found were dissected by Messrs. Berman and Gaylord, of the class of 1915, Yale Medical School.

LITERATURE CITED

GRUBER, WENZEL 1870 Bull. de l'Acad. imp. de St. Petersburg. 1871–72. Ueber einen vom Musculus Semitendinosus abgegangenen Musculus tensor fasciae suralis. Mélanges biol. Acad. imp. d. sc. de St. Petersburg, vol. 8, pp. 437–440.

1879 Ueber die ungewöhnlichen Musculi tensores fasciae suralis beim Menschen. Mélanges biol. Acad. imp. d. sc. de St. Petersburg, vol. 10, pp. 199–209.

GRUBER, WENZEL 1879 Beobachtungen aus der menschlichen und vergleichenden Anatomie, 2 Heft, Berlin.

HALLIBURTON, W. D. 1881 Remarkable abnormality of the musculus biceps flexor cruris. Jour. Anat. and Physiol., vol. 15, p. 296.

KELCH, WILHELM G. 1813 Abweichung des Biceps Femoris. Beiträge z. pathol. Anatomie, Bd. 8, art. 36, s. 42.

LEDOUBLE, A. F. 1897 Traité des variations du système musculaire de l'homme. Paris.

TESTUT, L. 1884 Les anomalies musculaires chez l'homme expliquées par l'anatomie comparée, leur importance en anthropologie. Paris.

1892. Les anomalies musculaires considérées au point de vue de la ligature des artères. Paris.

TURNER, W. 1872 Muscular system. Jour. Anat. and Physiol., vol. 6 (2d series, vol. 5), p. 441.

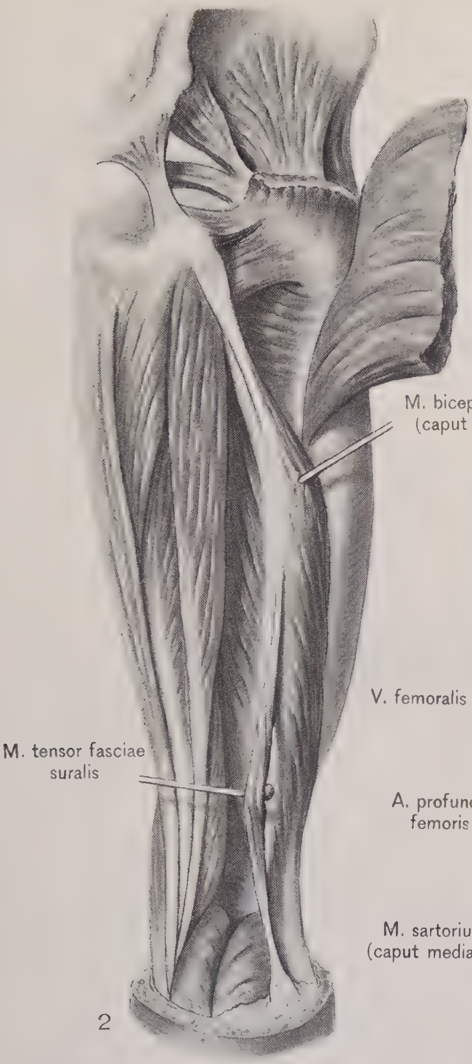
1885 Presence of an accessory sural muscle. Jour. Anat. and Physiol.. vol. 19, p. 334.

PLATE 1

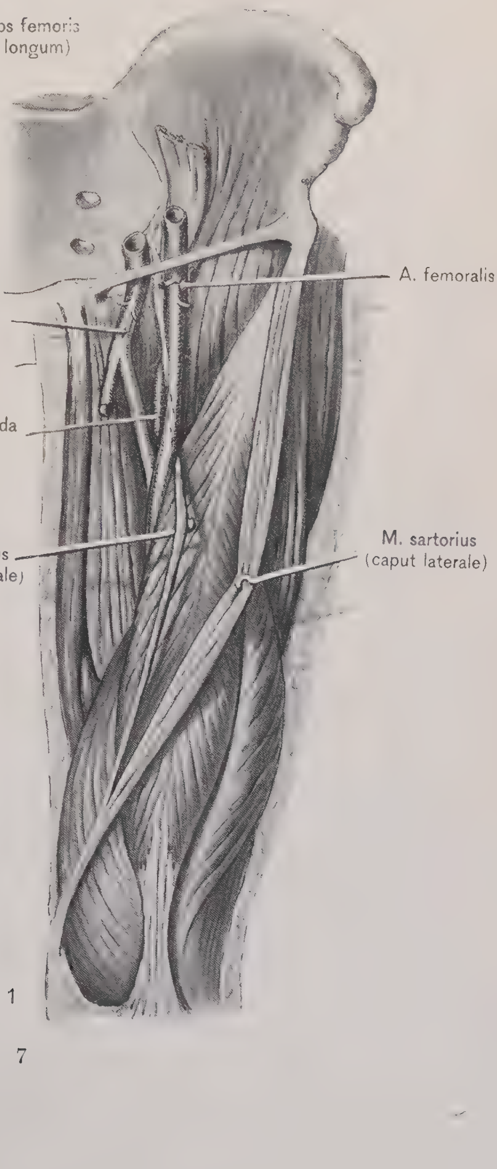
EXPLANATION OF FIGURES

1 Drawing from an actual dissection of the ventral aspect of the thigh. No detailed drawing of the dissection was attempted. The anomalous sartorius muscle with its partial duplicity and double head of origin should especially be noted. The medial or anomalous head passes between the femoral and profunda femoral arteries and then to its point of origin on the iliopectineal eminence; (see text for a further consideration of the sartorius muscle).

2 Drawing from an actual dissection of the dorsum of the thigh and the most cephalic portion of the sural region. The details of the dissection are purposely omitted in the drawing. The supernumerary tensor fasciae suralis muscle should especially be noted; (for a description of this muscle, see text).


M. biceps femoris
(caput longum)
M. tensor fasciae
suralis

2


A. femoralis
V. femoralis
A. profunda
femoris
M. sartorius
(caput mediale)
M. sartorius
(caput laterale)

1

ELECTRICAL HEATING OF PARAFFIN BATHS

R. M. STRONG

From the Hull Zoological Laboratory, University of Chicago

SIX FIGURES

In the autumn of 1910, I took up the problem of electrical heating for paraffin baths in the zoölogical laboratories of the University of Chicago. The system described by Mark[1] was considered, but certain features of his equipment did not seem to be suitable for the Lillie type of bath used in our laboratories. Some modifications were made, and these especially will be discussed in this paper. Observations on the amount of current employed and other data have been included with the hope that they may be useful to some readers. It should be noted here, that the system described in this paper is used with a 110 volts direct current. Changes would be necessary for an alternating current.

Different kinds of heating units were examined, and three were tried. The most satisfactory results have been obtained with so-called disc stoves, such as may be obtained on the market. One of these stoves is mounted on a metal frame, and its surface is in contact with the center of the paraffin bath bottom. The stove and its mounting are within an asbestos-lined box of galvanized iron which supports the bath and presumably affords some economy in the use of heat (fig. 1, *b*) besides being a protection against fire. A door will be seen in the side of this box, which gives access to the stove inside. The current used by the stove is controlled by a thermostat, located at the rear, right-hand upper corner (fig. 1, *t*) which operates an automatic switch in a case below (fig. 1, *s*). The switch case should be mounted in a more accessible position than is shown in figure 1. This bath will be designated as *A*, and another similarly equipped will be called *B*.

Various forms of thermostats were considered, and the adapted Reichert gas-regulator described by Professor Mark was tried for a time. It was found, however, that this requires an unreasonable amount of attention to keep it in order, and something which would be less easily injured was desired. There was no suitable location for a metal thermostat such as has been described by Land,[2] and it also seemed

---

[1] E. L. Mark, A paraffin bath heated by electricity. Am. Nat., vol. 37, no. 434, 1903, pp. 115–119.

[2] W. J. G. Land, An electrical constant temperature apparatus. Bot. Gaz., vol. 52, no. 5, November 1911, pp. 391–399; 4 text figures.

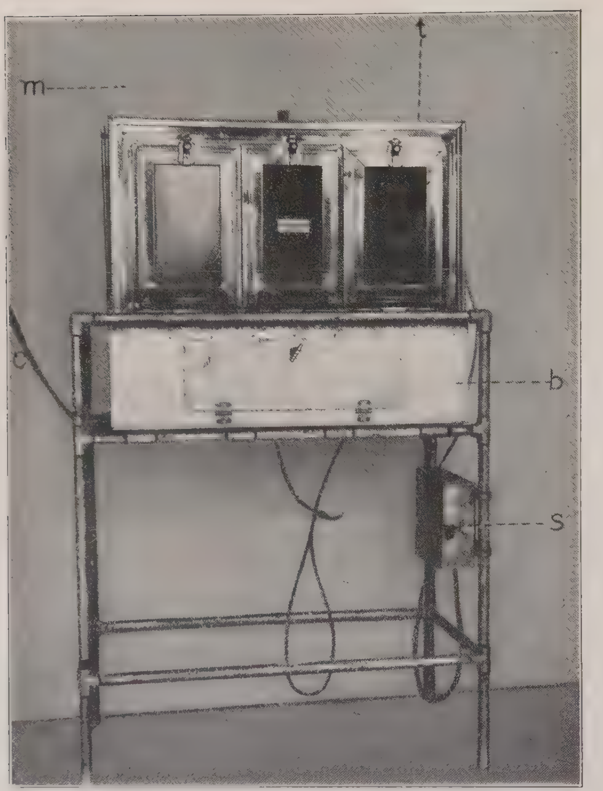


Fig. 1 From a photograph of paraffin bath equipped with electrical heating apparatus and supported by a galvanized iron box, *b*. The box is lined with asbestos. An electrical 'disc stove' is mounted inside the box with its surface in contact with the center of the paraffin bath bottom. The top of the thermostat adjusting screw appears at *t*; *s*, galvanized iron case containing automatic switch or 'cut-out;' *c*, cable supplying current to the apparatus; *m*, thermometer.

desirable to have a thermostat which would be controlled by the temperature of the water in the bath jacket.

The double branched tube, shown in figure 2, was designed with the idea of dropping all the glass portion of the apparatus down into the bath water jacket through the small opening which is provided for gas regulators. This arrangement was desired in order that as little as possible of the thermostat should be exposed to such injuries as might occur outside of the bath. The result is, that only the square vulcanite block and the parts above it (figs. 3 and 4) are exposed to view and to chance blows. The tube is suspended from the vulcanite block, just mentioned, by means of the flanges at the upper ends of the two branches.

In order to relieve the glass tube from lateral strains, it was found desirable to enclose the whole tube in a brass case which was fastened to the vulcanite block as may be seen in figure 4.

Mercury was poured into the tube until it entered the lower portions of both branches. Openings in the side of the brass case make it possible to view the mercury levels in the branches. The height of the mercury in branch *B* may be varied by an adjusting screw which regulates the level of the mercury in branch *A*. It may be set for a wide range of temperatures.

A platinum needle is suspended in branch *B* from a slender but stiff rod which is attached to an arm (fig. 4, *a*), at the base of one of the binding posts above (fig. 4, *b.p′.*). It has been found important to have the needle point well centered to avoid contact with incrustations which accumulate gradually on the inside of the tube above the mercury, sometimes, and which seem to conduct electricity to the column of mercury even when it has dropped below the needle point.

Various inside diameters were tried for the tube branches, and the most satisfactory have been about 6 mm. for branch *A* and 3 or 4 mm. for branch *B*.

The delicacy of the thermostat varies, of course, with the mass of the mercury and inversely, with the diameter of the mercury column in branch *B*. My experience has been that the greater the diameter of this mercury column, the longer may the apparatus be expected to run without attention. With much smaller diameters, it is necessary to clean branch *B* rather frequently, i.e., every few weeks. Accumulations of oxidized mercury near the point of 'make and break' in small bore tubes, cause the thermostat to work erratically. The use of oil to reduce the arcing and consequent oxidation of mercury only postpones the coming of trouble, in my experience.

The automatic switch used (figs. 5 and 6) is a mercury cup 'cut-out' designed and made by Mr. Julius Pearson, mechanician in the Ryerson Physical Laboratories at the University of Chicago. It has mercury cups which are deep enough to prevent mercury from splashing out when the switch-lever plungers descend or rise. The coil in the electromagnet is wound with a very fine wire, and it offers sufficient resistance to make a rheostat unnecessary. The cut-out is mounted on an asbestos board base. Upon the advice of an electrician, a piece of fuse wire (fig. 6, *f*) was inserted, but the maker regards this as superfluous.

A cheaper but (to my mind) less effective form of cut-out has been described by Land[3] which may be substituted for the one described here.

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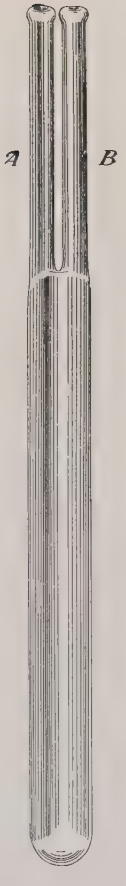
[3] W. J. G. Land, An electrical constant temperature apparatus. Bot. Gaz., vol. 52, no. 5, pp. 391–399.



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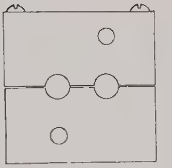

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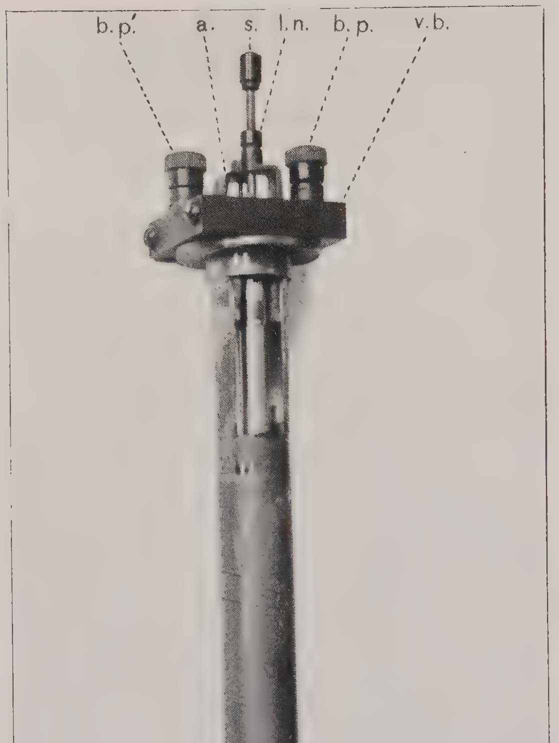

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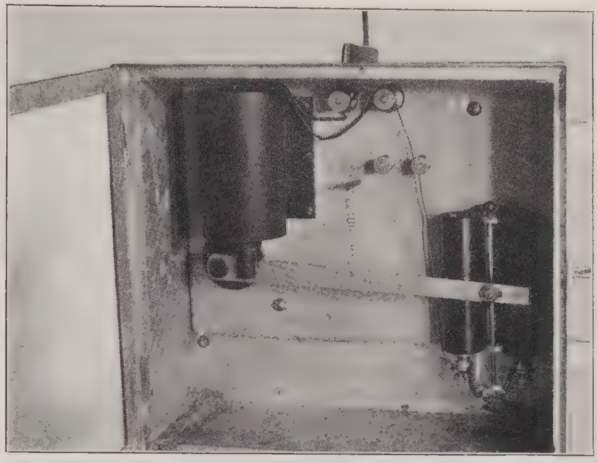

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Fig. 2 Glass portion of thermostat. × $\frac{2}{3}$. *A*, branch of tube which contains adjusting screw; *B*, branch containing platinum point for 'make and break' of circuit. This point may be about 2 cm. from the top of the branch. The level of the mercury in the other branch should be a little lower. The tube used in the thermostat which is shown in figure 4, had somewhat larger diameters.

Fig. 3 Diagram of vulcanite block which appears in figure 4, *v. b.* × $\frac{1}{2}$. The block is cut through its middle for convenience in mounting the glass tube (shown in fig. 2), which hangs by the flanges at the points indicated by the larger circles. The two halves of the block are held together by screws whose heads appear at the top of the figure. The positions of binding posts are indicated by the smaller circles.

Fig. 4 From photograph of thermostat complete. × $\frac{1}{2}$. The glass tube shown in figure 2 is here inclosed by a brass protector which is screwed to the vulcanite plate above. Openings near the top permit inspection of the mercury levels. Branch *A* of figure 2 is in view; *b.p.* and *b.p.'*, binding posts; *a*, arm which supports slender rod with platinum point; *s*, adjusting screw; *v.b*, vulcanite block shown in figure 3. The adjusting screw has a closely-fitting plug at its lower end and a small amount of mercury is placed above the plug as a seal. The sealed plug prevents mercury from slipping above the end of the screw.

Fig. 5 From photograph of automatic switch of 'cut out' in its case (fig. 1, *s.*). × 1/4.5. The front of the case is closed by a glass door, part of which appears at the left. The door is kept closed by a small padlock.

When electricity is being used by the stove, the switch lever (fig. 6, *l*) is down, and the plungers at its right hand end have their lower ends immersed in the mercury below. This arrangement completes a circuit for the stove. As the temperature of the bath rises, the mercury in the thermostat expands until the column in branch *B* (figs. 2, 4 and 6, *t*), rises to the level of the platinum point above and a contact occurs. Immediately a circuit is made for the thermostat through wires which join the heating circuit at *s* and *s′*, figure 6. The consequence is that the electro-magnet (fig. 6, *m*) is supplied with current, and a piston which is attached near the left hand end of the switch lever is pulled upward. This raises the switch lever, and the plungers at the right hand end of the lever are withdrawn from the mercury (as is the case in fig. 6) with a breaking of the circuit for the stove as a consequence.

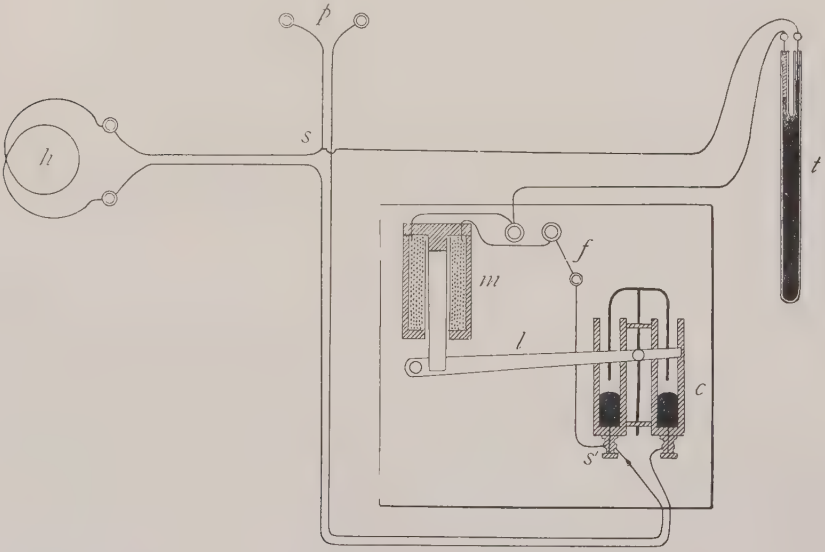


Fig. 6 Diagram of automatic switch and condensed wiring plan for the entire heating apparatus; *p*, binding posts for electric supply; *h*, stove; *t*, thermostat; *m*, electro-magnet; *l*, switch lever; *f*, fuse wire; *c*, mercury cups. The current which passes through the thermostat is shunted from the heating circuit at *s* and *s′*. The mercury in the cups and in the thermostat is shaded black. The diagram shows the thermostat in circuit with the current to the stove broken.

As the bath temperature lowers with the cooling of the stove, the mercury in the thermostat contracts until the platinum point is no longer in contact with the mercury in branch *B*. The thermostat circuit breaks, then, and cuts off the current to the electro-magnet (fig. 6, *m*) whereupon the levers descend and the stove is again placed in circuit. In figure 5, a coil spring will be seen above the switch lever and attached near its middle. This spring takes up some of the weight of the lever and its plungers, the electro-magnet not being strong enough to do the work unaided.

Bath *A* is 46 cm. high, 33.5 cm. deep, and 80 cm. wide. It is heated by a 770 Watt stove. A 550 Watt stove is used for bath *B* which is 51 by 38.5 by 57 cm. in size. Both stoves have been tested in service, and they were found using almost the exact amounts of current for which they are rated by the manufacturers. The two stoves were obtained from different makers.

Observations were made when the bath temperature was 55°C., and with different room temperatures, of the periods of rest and service, that is, of use and non-use of electricity by the stove. The stove is in service to some extent during the period when current is not being used. However, it furnishes heat to the bath during only a small part of a rest period. With a room temperature of about 21°C., both stoves were in circuit approximately half the time. For bath *B*, the periods were 13 to 13.5 minutes, and they were several minutes shorter for bath *B*. When the room temperature was only 16°C., the periods of service averaged about twice as long as the rests. During the winter, the room temperature was sometimes below 10°C., at night, but the paraffin was found melted and the apparatus in good order, the following morning. No actual observations, concerning the ability of the stoves to maintain the required temperatures when the room temperature was below 15°C., were made.

The number of kilowatt hours for a day of twenty-four hours, when the room temperature is about 21°C., would be, then, for bath *A* about 9.2; and bath *B* would use in the same time about 6.6 kilowatt hours of current. The cost of the heat for baths, thus equipped, can of course be estimated only by considering the local charge for electricity.

Observations were made for a period of about thirty-five minutes on the constancy of a thermostat which had a column of mercury in branch *B*, 3 mm. in diameter. The room temperature was about 21°C., and the bath was running at 55°C. During this period, there were five changes in the current which involved two periods of rest for the stove. No measurable changes in temperature for the bath were indicated by the thermometer employed, during this period. Later, a thermometer with graduations of 0.2°C. was used for a period of about one and one-half hours, when the difference between the lowest and the highest temperatures was 0.6°C. The thermostat was, of course, in good running order at this time.

The most satisfactory results have been obtained with the 770 Watt stove which was bought of the Simplex Electric Heating Company, and I am informed that their stoves have given the best results for others. They are located at Sydney and Auburn Streets, Cambridge, Mass., with a western office in Chicago, 1144–1146 Monadnock Block. This

770 Watt, 110 volts stove No. 1704 is listed at $8.50 with a 25 per cent discount to educational institutions. It has been in continuous service for over a year, except for a period of ten weeks during the past spring. Another stove, used for bath *B* and of less power, burned out recently and is being repaired. It is of somewhat different construction and was bought of another firm.

The glass tube shown in figure 1 was made by W. J. Boehm, 170 West Randolph Street, Chicago, at a cost of 65 cents. The mounting of this tube complete was done by the mechanician already mentioned in this paper for about $4.00, and his charge for the automatic switch apparatus was $15.00. The cost of both the thermostat and the automatic switch can, of course, be greatly reduced if some of the work on them can be done in the laboratory by the instructor or an assistant. A cheaper electro-magnet can be bought in the market and the switch may be adapted to it with fair results. The box supporting the bath and the case for the automatic switch were made by a local hardware firm at a small expense.

In conclusion I acknowledge helpful suggestions received from Prof. W. L. Tower in the planning of this equipment.

A PRELIMINARY REPORT ON THE ASYMMETRY OF THE BASAL GANGLIA

RICHARD W. HARVEY

From the Hearst Anatomical Laboratory, University of California

SIX FIGURES

Recent studies on the lateral ventricles of the brain (Harvey '11) have led to the observation that in a majority of the brains studied the volume of the left anterior horn was greater than that of the right. The brains on which these studies were made have been carefully preserved, and a further investigation of them has resulted in the observation that not only the anterior horns of the ventricles but also the basal ganglia of the cerebrum are asymmetrical. It seems very probable from a study of the relations between the ventricles and the ganglia that the asymmetry of the former is influenced in part at least by the asymmetry of the latter.

Asymmetry of the brain has long been maintained and the preponderance of weight of the right or left hemisphere given by different investigators. Broca, quoted in Testut, finds the right hemisphere to be heavier by 2 grams in the male, while in the female it is only a few centigrams heavier. He also finds that the frontal lobe has a preponderance of from 2 to 2.5 grams on the left side, so that the difference in favor of the right hemisphere is said to be due to the preponderance of the parietal, occipital, and temporal lobes. According to Mall, however, the frontal lobe is between 43 and 44 per cent of the weight of the cerebrum. It would seem from this, therefore, that the preponderance of a hemicerebrum depends largely on that of the frontal lobe.

Reichart infers from the literature collected by Ilberg and Ziehen that the question whether the hemispheres are alike in weight or whether one exceeds the other is by no means settled. Hitzig comes to the same decision. The former reporting from the Würzberg clinic says that an extrordinary number of brains show absolutely equal hemisphere weights. This similarity of weights is especially remarkable to him on account of the generally accepted belief in the greater function of the left hemisphere and in asymmetry of the skull which is so often encountered. Obersteiner also expresses the opinion that the hemispheres are of nearly equal weight, while Poirier and Charpy consider the difference in weight too small to be significant.

Franceschi, with whom a number of observers agree, finds the left hemisphere to exceed the right in weight in about the same number of cases as the right exceeds the left. Liepmann also considers the left hemisphere to predominate, and Pfister in weighing children's brains finds a preponderance of the left hemisphere.

Such diverse conclusions may be accounted for in part by the various methods employed in dividing the brain. Broca, for example, adopted as the limit of the frontal lobe the sulcus centralis (Rolandi), and the section was made probably to include that portion of the basal ganglia lying in the frontal lobe. Huschke, on the other hand, determined the boundary of the frontal lobe by cutting the brain at the sutura coronalis. Meynert, using still another method, divided the pallium from the brainstem and cut off the pallium of the frontal lobe at the sulcus centralis, therefrom obtaining the weights of the frontal lobes distinct from the basal ganglia.

It is evident that on account of the difficulty of separating the component parts of the brain and the resulting variety of methods used to obtain this separation, that at the present time there is no definite proof of a preponderance of weight in either hemisphere. The differences between the hemispheres that are found may be accounted for by the different methods of dividing the cerebrum, or by error in making the division.

The explanation of variations of brain weight is regarded by Donaldson as mainly dependent on the size of the constituent nerve elements. He believes the left hemisphere to be heavier than the right although he failed to find it so. He believes the greater part of the difference in weight due to axones and their medullary sheaths. In the larger brains the difference in weight is due to first, the greater number of neurones, second, the more generous development of the axones, and third, a combination of both these factors.

Smith finds frequent morphological asymmetry in the brains of Egyptians, the occipital pole of the left hemisphere projecting much further backward than the right in about 80 per cent of cases. This asymmetry of the brain influences the form of the cranium to such an extent that a distinct depression is formed in the left superior fossa of the occipital bone. Not only is the cranium almost invariably asymmetrical, but the projecting left occipital pole seems to bend the left superior longitudinal sinus to the right. It is suggestive that asymmetry of the brain and cranium may have a racial significance. Smith finds that while a symmetrical arrangement of the visual cortex occurs in less than 10 per cent of Egyptian brains, it is found much more often than not in the negro. The symmetrical cranium of the negro is therefore a sign of inferiority since there is not the greater specialization of the two hemispheres as in the white races in which cranial asymmetry is the rule.

When the observation of asymmetry of the anterior horns of the ventricles was made, an association between the excess volume of the ventricles and the preponderance of the frontal lobe was at once considered. The position of the caudate nuclei lying in the floor of the anterior horns and the bodies of the lateral ventricles, with the heads of these nuclei lying in the frontal lobes suggested that if they were found to be asymmetrical they might explain in part the excess weight of one of the frontal lobes.

Franceschi, quoted by Donaldson, shows a slight excess in weight of the basal ganglia of the left side, but an examination of the literature reveals nothing else definite on the asymmetry of the basal ganglia. In view of the paucity of information on this subject it has seemed profitable to undertake the present investigation.

In considering the asymmetry of brains hardened in formalin there must be taken into account the unequal shrinkage of brain tissue due to the preservative, and also the changes by drainage and evaporation, after the removal of the brains from the formalin. Likewise post-mortem alterations should be very carefully borne in mind.

Mall has shown that while the absolute weight of the cerebrum varies with changes in the strength of the formalin and during a period of nearly a year, the relative weight of one part of the cerebrum to the whole remains very constant. It therefore seems reasonable to presume that the relative volumes of the brains used in this study would remain fairly constant, since the relative densities probably would not vary greatly. The brains, which had been kept in 10 per cent formalin for periods exceeding one year, were those from which casts of the ventricles had been made. Since using them for that purpose they have been kept moist in a tight jar, subject to the same elements of drainage and evaporation. No data as to age, sex, race or condition at autopsy are available.

For the purpose of facilitating removal of the casts of the ventricles without tearing the brain tissue coronal sections were made at the level of the anterior extremities of the ventricles, at the foramina of Monro, and at the level of the pulvinar. Later, in order to compare the cross sections of the ganglia of the two sides an additional section was made between the latter two, passing approximately through the middle of the thalami.

Since dissecting out the basal ganglia for the purpose of obtaining their weights presents many difficulties and leads to many inaccuracies, while differentiation between the grey and white substance is sufficiently sharp to permit tracing the outlines of sections of the basal ganglia, a modified Born's method of reconstruction by means of wax plates is used in the preparation of models of the ganglia, by means of which the morphological features of the two sides may be compared.

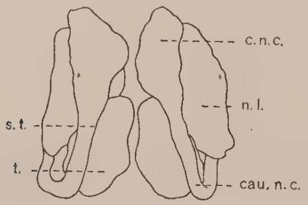
The frontal and occipital poles were removed from the brains by coronal sections, and the mid-portion of each brain containing the basal ganglia was cut into coronal sections on a brain microtome. Each section was 3.5 mm. thick. Wax plates were rolled out to the same thickness. The outlines of the sections of the ganglia were transferred to the wax in the following manner: A film of celluloid which is transparent was laid on a section and a tracing of the outline made on it in india ink. The tracing was then laid on the wax plate and transferred to it by means of a style. The tracings on the wax were cut out with a knife and trimmed down to agree with the celluloid pattern. The models were constructed by piling the wax plates, using as a guide line a point on the corpus callosum, and fusing the plates together with a hot iron.

The models yield nothing new so far as the morphology of the ganglia themselves is concerned, but assist in the objective conception of their form and relations to each other. In addition to this they show marked asymmetry. Detail in the morphology of the ganglia is of course lacking because of the thickness of the sections; but for purposes of comparison between the two sides and between different brains the models furnish a consistent picture.

The model shown in a dorsal view (fig. 1) presents on each side the caput nuclei caudati tapering dorsad into the cauda nuclei caudati, and extending from the substantia perforata anterior in a curve to the level of the foramen interventriculare. The convex surface looks dorsad and mesad, and is curved to form the floor of the cornu anterius. The oval thalamus lies ventrad to the nucleus caudatus and separated from it by the stria terminalis. The nucleus lentiformis is joined ventrad to the caput nuclei caudati, thus forming the corpus striatum. Between the nucleus lentiformis laterad and the thalamus mesad lies the capsula interna. Beneath the nucleus lentiformis (fig. 2) on each side lies the nucleus amygdalae in which terminates the cauda nuclei caudati.

With regard to the points of asymmetry exhibited by this model (No. 7) the caput nuclei caudati of the left side is slightly larger than the right. The thalami are fairly symmetrical. The left nucleus lentiformis is decidedly larger than the right. The dorsal view shows it to be longer anteroposteriorly, and the ventral view (fig. 2) emphasizes the greater transverse diameter.

Model No. 1 (fig. 4) is one of the largest of the series and shows marked asymmetry. Although the area of the dorsal surface of the left caput nuclei caudati is about the same as that of the right, the volume of the left is greater than the right. There is a marked bend in the body of the right nucleus, also seen in other models, as though produced by the fiber bundles of the internal capsule. This bend is especially prominent at the genu. The left nucleus lentiformis is placed further anteriorly than the right. The volumes of these nuclei are about the same. The right thalamus is about 3 mm. longer than the left while the vertical and horizontal diameters of one side about equal those of the other.



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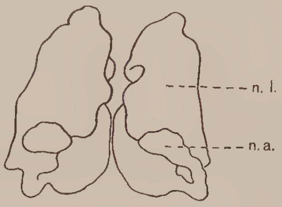

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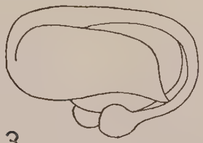

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Fig. 1 Dorsal view of model No., 7 of basal ganglia; *c.n.c.*, caput nuclei caudati; *cau.n.c.*, cauda nuclei caudati; *n.l.*, nucleus lentiformis; *t.*, thalamus; *s.t.*, stria terminalis.

Fig. 2 Ventral view of model No. 7 of basal ganglia; *n.l.*, nucleus lentiformis; *n.a.*, nucleus amygdalae.

Fig. 3 Side view of model No. 7 of basal ganglia.

A model of brain No. 2 was not reconstructed.

Model No. 3 (fig. 4) is one of the smallest of the series. It also shows marked asymmetry. The caput nuclei caudati of the left side is larger than the right. The right nucleus lentiformis has a greater horizontal diameter than the left, and the fusion with the head of the caudate is less extensive. The left thalamus is much larger than the right. The body of the caudate on both sides shows the bend of the genu of the internal capsule.

No. 4 (fig. 4) shows the left nucleus caudatus to exceed greatly the right in size. The bend in the body on the right side is slight, on the left it is absent. The brain from which this model was reconstructed was somewhat torn, so the cauda nuclei caudati on each side is not shown. The right nucleus lentiform is about equal in size to the left, but its anterior extremity is less fused with the caput nuclei caudati. The left thalamus is much longer than the right, and the shorter horizontal diameter of the left is compensated by the longer vertical diameter of that side. It is to be noted that the thinness of the thalamus occurs on the side on which the capsula interna shows a thicker posterior limb.

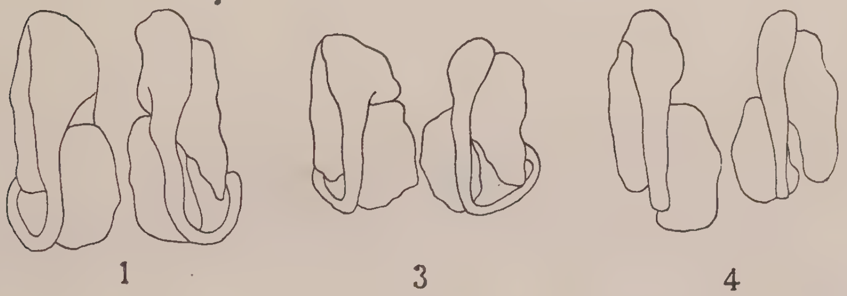
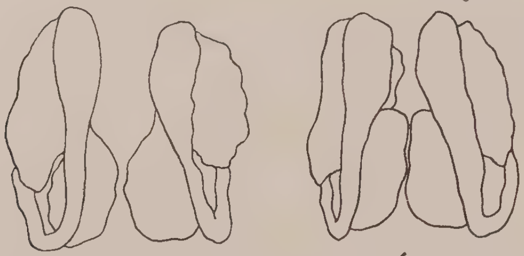


Figure 4

Model No. 5 (fig. 5). The volume of the left caput nuclei caudati is greater than that of the right. There is a noticeable bend in the body of the left nucleus at the genu of the capsula interna. The right nucleus lentiformis greatly exceeds the left in volume. The right thalamus is longer than the left (not shown in the drawing), while its horizontal diameter is less than that of the left. Likewise on the right side the posterior limb of the capsula interna is thicker than the opposite side.

In model No. 6 (fig. 5) the volumes of the left caput nuclei caudati is slightly in excess of that of the right side. No bends in the bodies occur. The right nucleus lentiformis greatly exceeds the left in volume. The right thalamus is smaller than the left, and on this side the posterior limb of the capsula interna is thicker.

Model No. 8 (fig. 6) shows the bends in the bodies of the nuclei caudati. The nuclei themselves are fairly symmetrical. The right nucleus lentiformis preponderates. The tuberculum anterius thalami is more prominent on the right side, and the horizontal diameter of the thalamus is greater on the right side than on the left. The thickness of the posterior limb of the capsula interna of the right side corresponds with the lateral compression of the thalamus on the same side.



5 6

Figure 5

No. 9 (fig. 6). The volume of the right caput nuclei caudati exceeds the left. There is a marked bend in the body of the left nucleus. The right nucleus lentiformis is larger than the left. The volume of the left thalamus exceeds the right.

Model No. 14 (fig. 6). The only striking point of asymmetry is the excess volume of the right thalamus, although its lateral compression as compared with the opposite side is marked. Corresponding with this compression is the greater thickness of the posterior limb of the capsula interna on this side.

A comparison of the nine models shows that the convex surface of the caput nuclei caudati is more extensive on the left side than on the right in about 78 per cent of cases. Since the left is the side on which the excess volume of the anterior horns was found, it seems possible that the extent of the floor at least partly determines the volume of the ventricle. This view is supported by the observation that those brains in which the left anterior horn was enlarged showed a corresponding extension of the dorsal surface of the left nucleus caudatus. In table 1 the volumes of the anterior horns are given in cubic centimeters. Those underlined correspond with the surfaces of the caudate nuclei showing the excess areas.

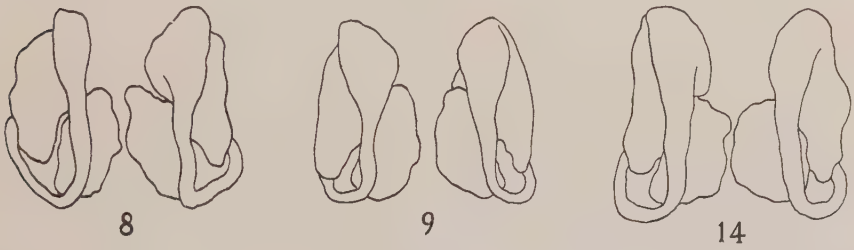


Figure 6

TABLE 1

	NUMBER OF CAST									
	1	2	3	4	5	6	7	8	9	10
Left	3.5	8.2	5.7	3.2	5.5	1.2	0.6	7.2	1.0	2.4
Right	3.9	7.3	4.4	2.9	4.3	1.0	0.5	7.4	2.0	1.7

The areas corresponding with cast No. 1 were about equal on both sides. The brains from which casts Nos. 2 and 10 were made were so torn in removing the casts that they could not be used in the reconstructions.

The left nucleus caudatus, then, exceeds the right in size in 78 per cent of the cases; the right nucleus lentiformis exceeds the left in 55 per cent; the left thalamus exceeds the right in 55 per cent, although the transverse diameter of the right exceeds the left in the same number of cases. The posterior limb of the capsula interna is thicker on the left side in 55 per cent of the cases, or in other words, it is thicker in those cases in which the thalamus seems to be laterally compressed. This series of models seems to show that the asymmetry of the basal ganglia is an element to be considered in determining the preponderance of a hemicerebrum. As stated before, it seems impracticable to weigh the nuclei, but if it be assumed that in the larger nuclei there is a difference in weight due to the greater number of nerve elements, then the preponderance of the left caput nuclei caudati will partly account for the asymmetry of the frontal lobes. The asymmetry of the remainder of the cerebrum also should be slightly influenced by the asymmetry of the basal ganglia.

The asymmetry of the posterior limbs of the internal capsules, suggested by this series of models, leads to the question of an excess of axones on one side.

Throughout the animal body there are repeatedly exemplified the morphological interrelationship of organs and parts of organs, and the morphological characters of organs resulting from the processes of growth. For example, the relation of the cranium to the pallium during development may be a factor in the production of the gyri, because as the cortical grey substance increases in amount in accordance with an increased bulk of body, the surface area may be limited by the capacity of the cranial cavity. The pallium is therefore thrown into folds. On the other hand, that the form of the cranium may be influenced by the asymmetry of the brain has been shown by Smith. It may be presumed that structures so intimately related as the basal ganglia and the internal capsule influence one another morphologically. The models show this in the bending of the nucleus caudatus at the genu of the capsula interna. Further, the genu conforms with the interval between the tuberculum anterius of the thalamus and the caput nuclei caudati.

SUMMARY

1. In nine brains the nucleus caudatus on the left side exceeds the right in size in 78 per cent of the cases.

2. The increased size of the left caput nuclei caudati seems to determine partly the greater volume of the left anterior horn of the lateral ventricle. The excess volume of the anterior horn of the left lateral ventricle corresponds in all cases examined with the increased size of the left caput nuclei caudati.

3. The right nucleus lentiformis exceeds the left in about half the series of brains, and the left thalamus exceeds the right in a like number.

4. The interrelations of the basal ganglia and the internal capsules may determine the morphological characters of these structures.

In conclusion, it seems possible that not only may the preponderance of a hemicerebrum depend on the pallium, but also on the asymmetry of the basal nuclei. The entire question of asymmetry of parts of the brain is one requiring prolonged study to which the present paper is but preliminary.

BIBLIOGRAPHY

DONALDSON, H. H. 1905 The growth of the brain. Contemporary Science Series, vol. 24.

FRANCESCHI, G. 1888 Bullettino della Scienze mediche (Bologna), no. 1–2, 3–4.

HARVEY, R. W. 1911 The volume of the ventricles of the brain. Anat. Rec., vol. 5, no. 6.

HITZIG, E. 1898 Neurol. Zentralblatt, S. 1119.

HUSCHKE, E. 1854 Schädel, Hirn und Seele. Jena.

ILBERG Allgem. Zeitschrift f. Psychiatrie. Bd. 60, S. 346.

LIEPMANN H. 1905 Neurol. Zentralblatt, S. 1016.

MALL, F. P. 1909 On several anatomical characters of the human brain, said to vary according to race and sex, with especial reference to the weight of the frontal lobe. Am. Jour. Anat., vol. 9.

MEYNERT, TH. 1867 Vierteljahrschrift für Psychiatrie. Bd. 1.

OBERSTEINER, H. 1901 Anleitung beim Studium der Nervösen Zentralorgane. S. 144.

Pfister, H. 1903 Neurol. Zentralblatt.

Poirier et Charpy 1899 Traité d'anatomie humaine, vol. 3, p. 744.

Reichardt, M. 1906 Über die Untersuchung des gesunden und kranken Gehirns mittels der Wage. Würzburg.

Smith, G. E. 1907 On the asymmetry of the caudal poles of the cerebral hemispheres. Anat. Anz. 30, p. 574.

Testut, L. 1911 Traité d'anatomie humaine, vol. 2, p. 731.

Ziehen, Th. 1899 Lehrbuch der Anatomie des Nervensystems, S. 382.

BOOK REVIEW

Edinger's Lectures on the Central Nervous System, Eighth edition. Vorlesungen über den Bau der nervösen Zentralorgane des Menschen und der Tiere. Bd. I. Das Zentralnervensystem des Menschen und der Säugetiere. Achte umgearbeitete und sehr vermehrte Auflage. Leipzig, F. C. W. Vogel, 1911.

The eighth edition of Edinger's Lectures, like the seventh edition (see Anatomical Record, vol. 2, 1908, p. 273), appears in two volumes which are practically independent, the first volume being devoted to man and mammals and the second (which is not yet ready) to the comparative anatomy of the infra-mammalian vertebrates. The first volume of this revision is again greatly enlarged as compared with the previous edition, having grown from 398 pages to 530 pages with many new figures. The new illustrations are selected from a wide range of material, many of them being very helpful schemata. Teaching neurologists have been very greatly helped by Edinger's clever diagrams and graphic descriptions, and the new schemata in this volume place them under renewed obligations.

Brief summaries of pathological data are introduced only where they shed direct light upon anatomical and physiological relations. An especially useful summary of this sort is appended to the description of the medulla oblongata.

After the usual introductory chapters devoted to elementary principles, form relations, etc., Edinger begins his exposition of the functional analysis of the nervous system with the fundamental distinction between the somatic and visceral nervous systems. The arrangement of the four primary longitudinal columns (somatic and visceral sensory, somatic and visceral motor) of the spinal cord and medulla oblongata are compared by the aid of diagrams which conform to the scheme now generally employed in America, save that the ventro-lateral series of motor nuclei in the oblongata (motor V, motor VII and nucleus ambiguus) are reckoned with the somatic series.

Much valuable new material and several excellent diagrams on a visceral nervous system are added. These changes mark a notable advance over the previous edition. Throughout the remainder of the text also there has been a complete revision and improvement in the form of presentation, in addition to much new matter, many minor defects and inconsistencies of the former editions being eliminated. The description of the olfactory apparatus, in particular, is much clearer. The chapters on the cerebral cortex contain valuable comparative data which will prove helpful to students of psychology and animal behavior.

The brief excursus in psychology in the previous edition is here expanded into a twenty-page chapter. The fact that the cerebral cortex arises to a position of prominence rather late in the phylogeny is used as the basis for a division of the brain into a palaeencephalon and a neencephalon, the latter including the cerebral cortex and its dependencies. In the palaeencephalon are centers for all sensory receptors and for motor coördination. Here individual new relations between these elements can be effected, but no associations established nor memory pictures built up out of several components. It is the bearer of all reflexes and of many instincts.

While the cortex is by no means so sharply separated from the rest of the brain, either from structural or functional standpoints, as Edinger's scheme implies, yet his analysis is, when broadly considered, correct. The notable exceptions and evident transitional steps in lower vertebrates do not invalidate the scheme for higher vertebrates, if not too rigidly applied.

In this work Edinger has again revealed his genius for graphic presentation and shown himself a stimulating leader in one of the most difficult fields of modern research.

C. Judson Herrick.

BOOKS RECEIVED

The receipt of publications that may be sent to any of the five biological journals published by The Wistar Institute will be acknowledged under this heading. Short reviews of books that are of special interest to a large number of biologists will be published in this journal from time to time.

AN INTRODUCTION TO THE STUDY OF THE PROTOZOA, with special reference to the parasitic forms, E. A. Minchin, M.A., Ph.D., F.R.S., professor of protozoology in the University of London, illustrated, 520 pages including index, 1912, $6.00. Longmans, Green and Company, New York.

EXPERIMENTAL PHYSIOLOGY, E. A. Schafer, F.R.S., professor of physiology in Edinburgh, with eighty-three illustrations, 112 pages, 1912, $1.35. Longmans, Green and Company, New York.

THE ANATOMICAL RECORD, VOL. 7, NO. 2
FEBRUARY, 1913

LEONARD WORCESTER WILLIAMS

LEONARD WORCESTER WILLIAMS

Dr. Leonard Worcester Williams, the son of Dr. Mason F. and Mary Worcester Williams, was born in Muskogee, Oklahoma, July 8, 1875. He met his death in an elevator accident in the Harvard Medical School, September 26, 1912.

His parents were attracted to what was then called Indian Territory, where his grandfather had been a pioneer missionary, by the opportunities for helping the Indians, and here his father, a graduate of Princeton, worked as physician and sometimes as pastor and teacher until his death, a little over three years ago. Here Leonard received his early education, mostly at the hands of his parents, but as he grew older there came the necessity for other instruction. The schools of the Territory were poor and so he was sent, at the age of thirteen, to a preparatory school at Hanover, Indiana. Next he entered Hanover College where he got his first introduction to science. The hills along the shores of the Ohio River are rich botanically and the rocks contain numerous fossils, and here he spent many hours collecting. In 1895 he was graduated from Hanover College with the degree of bachelor of arts.

Immediately on graduation he received the appointment of professor of natural science in Henry Kendall College, a small mission college in his native place. Here he worked for two years, giving all of the scientific instruction in the college, but he was far from satisfied with his place and his equipment. He needed more training, a deeper insight into nature, and so he surrendered his position and entered Princeton University as a graduate student. Here he came chiefly under the instruction of Drs. Dahlgren and McClure, spending his summers at Woods Hole and beginning his work on the anatomy of the squid. In 1899 Princeton gave him the degree of master of arts.

From Princeton he went to Brown University to study with Dr. Bumpus. Here he finished the account of the structure of the squid and received the degree of doctor of philosophy in 1901. Then followed work with Dr. Mead on the Rhode Island Fish Commission and in 1903 an appointment as assistant professor of biology in Brown University, a position which he held until 1907. During these years at Providence his work, aside from teaching, was largely in economic lines, but several of his papers have a marked morphological character.

In 1907 he was called to the Medical School of Harvard University as instructor in comparative anatomy. Dr. Minot had become the head of this newly established department and it was his desire to place it in every way in the forefront. Dr. Williams was a skilled dissector and he had obtained from Dr. McClure a training in the methods of display of anatomical specimens which now stood him in good stead. A large part of his time was devoted to building up an anatomical collection which was intended eventually to cover all sides of the subject. His standards were very high; every specimen admitted must illustrate and illustrate well, some important fact or structure. One realizes, as he walks along the corridors where these specimens are exhibited, that they have taken no little patience and skill to prepare, and also that they show something more—a full appreciation of the fundamental facts of comparative anatomy. Besides this work, which speaks for itself, and several investigations of importance in morphological lines referred to below, Dr. Williams gave instruction in comparative anatomy to both medical and dental students.

While at Harvard he spent most of his summers in one of the laboratories at Woods Hole or in that at Harpswell. At the latter place he began a detailed study of the anatomy of Myxine, paying especial attention to the circulatory system. In the winter of 1910 he went to Freiburg where he spent the second semester, working chiefly under those masters, Drs. Gaupp and Keibel. While there he attended the Anatomical Congress at Brussels and the Zoological Congress at Graz, returning home in the fall of the same year.

On March 9, 1904, Dr. Williams was married to Miss Martha R. Clarke, the daughter of Professor Clarke of Brown University.

She with two children, Mary Frances, aged seven, and Henry Franklin, aged five, survive him.

Personal contact, extending over several years, had endeared Dr. Williams to me and I hesitate to put my opinions and estimates into words. Foremost among his characteristics was the spirit of helpfulness. He was always ready, yes anxious to assist in every way possible, in every project that appealed to him, and his interests were catholic. He was a most careful and accurate investigator, and his knowledge of comparative anatomy was very broad and thorough. Had he lived he would doubtless have stood among the very first of American comparative anatomists. Often have I consulted with him as to the details of some problem and have always found him informed at least as to its broader features and not infrequently as to its details. He was thoroughly honest in his studies and he had no more severe critic of his work than himself. Then he was sympathetic. Many things outside his special work made their appeal to him, and he was interested in every student who came under him.

His work and his worth were appreciated by all who came in intimate contact with him, and as I write, there are letters before me from German, English and American anatomists, all expressing the highest opinions of the student and the man. Some extracts from a memorial adopted by the faculty of the Harvard Medical School may be quoted here:

> Dr. Williams was a naturalist by instinct and education, and took great delight in examining marine creatures of all sorts. In this way he acquired rare technical skill in dissection and broad knowledge of the structure of animals. In 1907 he joined the Department of Comparative Anatomy, and became at once a welcome and most valuable member of the staff. Exquisite preparations remain as permanent mementos of his industry, and his publications are those of an earnest student, careful, painstaking and exact. . . . . In recognition of loyal service, freely rendered throughout the five years that Dr. Williams was our associate, we record our high appreciation of his labor in our behalf, and our deep sense of loss in his death.

Dr. Williams was member of the American Association of Anatomists, the Society of Zoologists, the Society of Naturalists, a fellow of the American Association for the Advancement of

Science, and a member of the council of the Boston Society of Natural History.

Dr. Williams published several minor notes and book reviews in Science and the American Naturalist which were characterized by a clear insight into the main features of the matter under discussion and an adequate valuation of the merits and defects of the work reviewed. Besides these, which will have no further mention here, he was the author of several papers which demand some notice. These are as follows:

The vascular system of the common squid. American Naturalist, volume 36, pp. 787–794, 5 figures, 1902. In this paper, for the first time there was given a brief but accurate description of the main vessels and the capillary circulation of the decapod cephalopods. The difficulties of injection were many, because the intrinsic muscles of the vessels contract upon irritation. Williams was able to devise a technique which obviated the difficulties, immersion of the animal in a solution of amyl nitrite being a prominent feature. He demonstrated the existence of large sinuses, beyond the capillaries and before the beginning of the smaller veins, these being a part of the blood vessels and not a specialized portion of the body cavity.

Habits and growth of the lobster, and experiments in lobster culture. Twenty-third report of the Commissioners of Inland Fisheries of Rhode Island for 1903, pp. 57–86, 4 figures, 1903. This paper, in which Dr. Williams was associated with Professor Mead, is largely a summary of facts concerning the life history of the lobster and a statement of the unsolved questions, together with a description of the methods found available for raising the young lobsters through the critical period.

Notes on the marine Copepoda of Rhode Island. American Naturalist, volume 40, pp. 639–660, 23 figures, 1906. In this are enumerated twenty-seven species of copepods found in Rhode Island waters, three of them being new. With the exception of a paper by W. M. Wheeler, this was the first study of the American species of this group, so important in the food supply of economic fishes.

The significance of the grasping antennae of Harpactoid Copepoda. Science, volume 25, pp. 225–226, 1907. In some Copepoda both pairs of antennae are converted into grasping organs. Williams points out that in these species there is a prolonged embracing of the female, beginning before the moult, and only after this is the spermatophore placed.

List of the Rhode Island Copepoda, Phyllopoda and Ostracoda with new species of Copepoda. Thirty-seventh report Commissioners of Inland Fisheries of Rhode Island, pp. 67–79, 3 plates, 1907. This enumerates 41 copepods, 10 phyllopods and 2 ostracods as occurring within the waters of the state, two of the copepods being new.

The stomach of the lobster and the food of larval lobsters. Thirty-seventh Report of the Commissioners of Inland Fisheries of Rhode Island, pp. 151–180, 16 figures, 1907. This is a paper which should be accessible in all laboratories where the lobster or cray-fish are dissected by students, for it describes in detail the structure of the stomach, its walls, muscles, straining apparatus, etc. A new conception of the function of the gastroliths is advanced—these are stores of lime which serve to harden the gastric teeth so that the animal can devour its cast shell, this being utilized as a source of calcareous matter for hardening the rest of the skeleton. It is shown, also, that a large proportion of the food of the young is afforded by the Copepoda.

The structure of cilia, especially in gastropods. American Naturalist, volume 41, pp. 545–551, 2 figures, 1907. In a larval gasteropod cilia were found which showed the structural and physiological relations better than usual. From a study of these Dr. Williams was led to support the generally accepted theory that all protoplasmic processes (pseudopodia, cilia, flagella and the suctorial tenacles of Acinetaria) are formed on the same plan. Each consists of a contractile protoplasmic sheath with a fluid or solid core. The differences between the various kinds are brought about by the differentiation of contractile and non-contractile portions, differently arranged, in the protoplasmic sheath.

The later development of the notochord in mammals. American Journal of Anatomy, volume 8, pp. 251–284, 20 figures, 1908. This paper discusses not only the notochord after its formation, but the origin of the vertebral column as well. It is pointed out that the sclerotome does not segment as such, and the development of the looser and denser sclerotomic tissue is traced up to the formation of cartilage. The notochord at first enlarges intravertebrally and finally disappears in this region with the ossification of the centra. The intervertebral portions are traced into the nuclei pulposi of the intervertebral discs. The cytomorphic changes of the notochordal tissue are also followed.

The anatomy of the common squid, Loligo pealii Lesueur. Brill, Leiden (Holland) 1909, 82 pages, 16 text figures and 22 figures on 3 plates. This is a very complete account of the structure of the squid, which, unfortunately, is published in a very small edition and so cannot have the use which it should have in our laboratories. It is a most careful piece of work, but is incapable of any adequate summary in a limited space.

The somites of the chick. American Journal of Anatomy, volume 11, pp. 55–100, 1910. This is closely allied to the notochordal paper just alluded to. It defines the parts of the somites, and traces the fate of the several parts in somites from the occipital, cervical, trunk and caudal regions of the chick, thus affording a secure basis for meristic homologies.

The intertubercular or bicipital foramen of the humerus of the guinea-pig. Science, N. S., volume 36, p. 192, 1912. This describes a foramen at the head of the humerus for the passage of the tendon of the biceps muscle which was found completely inarched in 17 humeri and almost enclosed in 25 more, out of a total of 125 skeletons.

For the past two years Dr. Williams has been engaged upon a detailed account of the anatomy of the guinea-pig, designed for those laboratories where this useful animal is made the basis of other investigations. The part relating to the skeleton is practically complete and it is hoped that it may be published soon. For its illustration he had made most careful drawings, executed in a truly artistic manner. For this purpose Dr. Williams mastered the technique of oil monochrome. He had made considerable studies of other parts of the guinea-pig, especially certain portions of the nervous system. As indicated above he had done considerable work upon Myxine, but for the past two years this had been set aside for the guinea-pig.

J. S. KINGSLEY.

THE RELATION OF WEIGHT TO LENGTH IN THE SMOOTH DOG FISH, MUSTELUS CANIS

SELIG HECHT

From the Biological Laboratories of the College of the City of New York

ONE FIGURE

In a forthcoming paper on the correlations among the body measurements of the weak-fish, Cynoscion regalis,[1] W. J. Crozier and the writer have demonstrated that the weight of the weak-fish is a function of the total length. The relation is such that the weight of a given specimen is equal to a constant times the *cube* of the length. Hatai[2] has recently shown that the length of the leopard frog is a function of its weight. He finds that the ratio of the weight to the length is not one of a simple third power relation, but that length is a complicated logarithmic function of weight, involving three constants. He, however, gives only the formula, without stating his method or giving his actual measurements.

In the course of some work on the smooth dog fish, Mustelus canis, Mr. George G. Scott of the College of the City of New York measured the weight and length of 115 specimens. It therefore occurred to me to determine the relation of weight to length in this species also. I wish to express my indebtedness to Mr. Scott for the kind permission to use the data on which this paper is based.

By 'length' is meant total length, from the tip of the snout to the extreme tip of the tail; by 'weight' is meant total weight after the surface water had been removed. Mr. Scott informs me that none of the specimens examined were 'abnormal' with regard to the size of the gonads. In this connection it is to be noted that sex does not influence the relation of weight to length. To be correlated with this, is the fact that for this species Kellicott[3] has shown that the sexes cannot be distinguished with respect to either the relative (to the total weight) or the absolute weights of the brain and visceral parts.

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[1] To be issued by the U. S. Bureau of Fisheries.

[2] Anat. Rec., vol. 5, pp. 309–312, 1911.

The measurements are given in graphic form in figure 1, where length is abscissa and weight is ordinate. A number of the points, particularly in the region of 60 to 85 cm., represent duplicates and triplicates. As was found in the case of the weakfish, the smooth curve drawn through the plotted points is of the form

$$y = ax^3$$

where y represents weight, x represents length, and a is a constant whose value depends on the units used. It is clear, therefore, that the weights of two dog fish are to each other as the cube of their lengths. The constant a is determined from the curve in figure 1. For a series of lengths 10 cm. apart, the lengths and weights are substituted in the above equation, and the equation is then solved for a. The value thus found is

$$a = 0.00274 \pm 0.00005$$

and the formula for weight in terms of length assumes the form

$$\text{weight} = (0.00274)\ (\text{length})^3.$$

To test the value of this equation table 1 was constructed. In the second and third columns are given the average lengths and weights of the fish whose lengths fall within the groups indicated in the first column. In the fourth column are given the calculated theoretical weights for the average lengths shown in the second column. The last column gives the percentage deviations of the calculated from the average weights. The deviations are seen to be very small.

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[3] Am. Jour. Anat., vol. 8, p. 321, 1908.

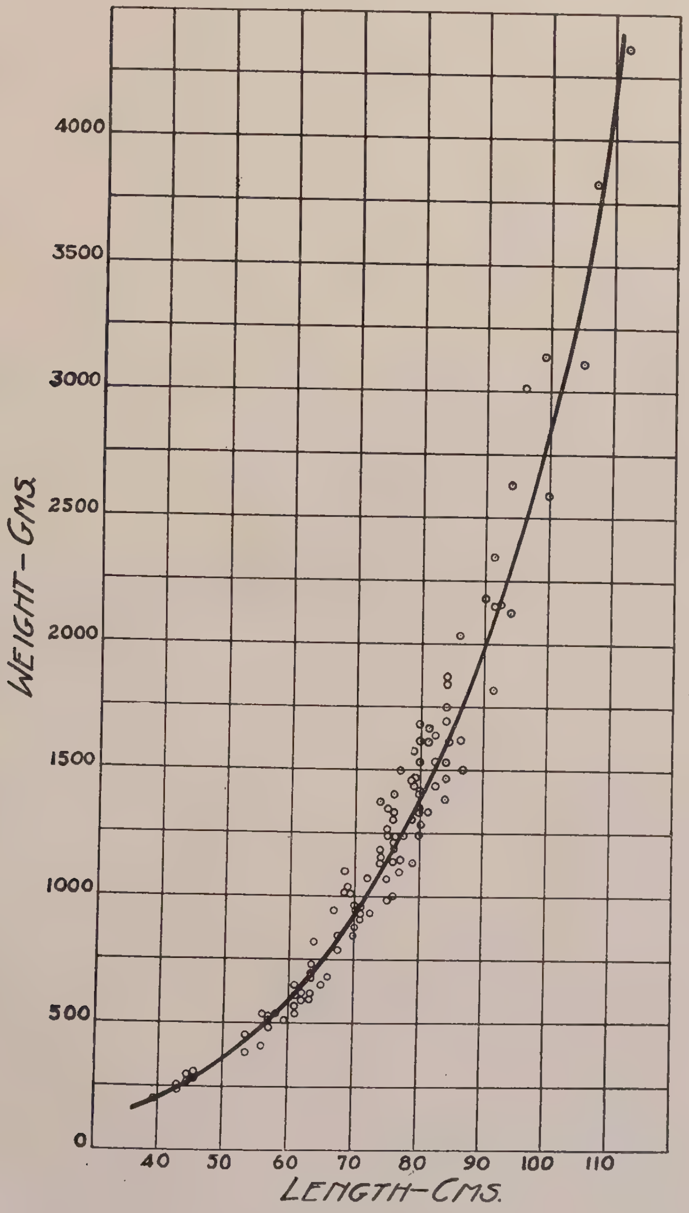

Fig. 1 Chart showing relation of weight to length in 115 specimens of Mustelus canis

TABLE 1

A comparison of the actual average weights and the calculated weights according to the formula, for lengths given in the second column

LENGTH GROUP	AVERAGE LENGTH	AVERAGE WEIGHT	CALCULATED WEIGHT	PERCENTAGE DEVIATION
cm.	*cm.*	*grams*	*grams*	*per cent*
40–50	43.56	264.1	259.3	1.8
50–60	56.38	483.2	491.2	1.6
60–70	64.64	753.3	740.3	1.7
70–80	74.91	1193.2	1152.0	3.3
80–90	82.34	1544.4	1530.0	0.9

The conclusion to be drawn from the data presented, seems to be that there is a constancy of form within the species studied, which is adhered to throughout the life of the individual. The relation of form to mass is clearly indicated in the young fish, and is continued with apparently mathematical accuracy as the fish increases in length and weight.

THREE FORMS OF THE HUMAN NOSE

ROBERT BENNETT BEAN

From the Medical Department, Tulane University

The three most distinct forms of the human nose appear characteristically in different parts of the earth and the forms are clearly geographical, evolutional, and developmental. The first of the three is the under-developed nose resembling that of the infant, and this form has been called by me the 'hypo-phylo-morph;' the second is a massive nose, the 'meso-phylo-morph;' and the third is the thin, high, long, narrow nose, the 'hyper-phylo-morph.'

The hypo-phylo-morph nose is flat, broad, and short, with flat depressed bridge, upturned tip, and the nostrils open forward rather than downward. The nostrils flare and are wide open, and the extremity of the nose is uplifted or tilted back so that an instrument may be inserted horizontally along the floor of the nasal fossa without interference by the alae. The nasal ridge, or the bridge of the nose, is flat, because the nasal bones do not form a steep roof over the nasal passages by their apposition along the median line. The articulation of the nasal bones with the frontal bone is a gentle curve and not an abrupt transition. The supraorbital ridges and glabella are not prominent, nor the frontal sinuses large in association with this form of nose, but the cheeks are full, and the eyes prominent, therefore the front of the entire face is somewhat flat, although the lips project from a small mouth. The hypo-phylo-morph nose is essentially the nose of the infant.

The hypo-phylo-morph nose is found especially among the Malays and Negritos, as they exist today in the Malay peninsula, Java, Sumatra, Borneo, Celebes, and the Philippine archipelago, as well as among the Pigmies, Bushmen and Hottentots of Africa. It is also found in a modified form in Burma, Siam, Cambodia, Tonkin, Annam, in India, China, Japan, Mongolia, and among the true negroes of Africa and America. The form dwindles away through Siberia, Lapland, Finland and Russia into Europe, where the hyper-phylo-morph nose appears. The form also dwindles away through the Eskimos and Indians of the Americas, among the Polynesians and the other inhabitants of the Pacific Islands, and among the pseudo-negroes of north and east Africa, in all of which peoples the meso-phylo-morph nose appears. The hypo-phylo-morph nose is most emphatic among the women of all the countries where it appears, but is also to be seen among the men.

The meso-phylo-morph nose is massive, long and broad, not very high, with apparently depressed root due to overhanging brows and glabella: it has a straight bridge, and nostrils that open downward and slightly forward. The outlines of the nose are usually straight. Looked at from in front, the lines of contact of the nose with the face on each side are straight, and slant away widely from the inner angles of the eyes to the alae of the nose. Looked at from the side the bridge of the nose is straight or very slightly aquiline from root to tip, and the lower border (base) of the nose is straight from a point just over the akanthion to the tip of the nose, although the tip may sometimes dip below this straight line. This line is not long in relation to the breadth of the nose, but it is absolutely as long as the same line in the hyper-phylo-morph nose, and may be even longer when the nose is unusually large. The nose looks flat, due to its great breadth, when it is actually a high nose. The alae flare little although the apertures of the nostrils are large, due to the great width of the nose. The nasal bones form a more acute angle at their apposition than in the hypo-phylo-morph nose, and they pass abruptly above into the frontal bone, where the overhanging brows and the glabella give the root of the nose a depressed appearance. The malar and zygomatic bones are large and project, and the jaws are prominent both in front and at the sides of the face. The orbits are large, the bony sinuses about the nose are of great size and the lips are thick. The result is that the whole face is large, and the nose conforms with its surroundings.

The distribution of the primary forms of the meso-phylo-morph nose center among the inhabitants of the Deccan and Ceylon, among the Polynesians and the inland tribes of the Philippine Islands, Java, Sumatra, Borneo, and Celebes, and it assumes its most exaggerated form among the Tasmanians, Australians, Melanesians, pure Negritos, and true negroes. The form exists somewhat modified among the peoples who have the hypo-phylo-morph nose, and is especially emphatic among the men, although it appears among the women. It fades away through northern Asia, in central Europe, through southern Asia towards the Mediterranean basin, and in eastern and northern Africa, at all of which points it merges into the nose of the hyper-phylo-morph.

The hyper-phylo-morph nose is long, high and narrow, with high root, bridge and tip, the nostrils flare but little and open almost directly downward. The nostrils may even open somewhat backward in the exaggerated forms, as in the Jew, for instance. The nose appears prominent and may seem larger than it really is, inasmuch as the jaws are not prognathous, and the brows and glabella do not overhang the nose; the forehead and chin may even recede leaving the nose projecting from the middle of the face. The nose may be retroussé, straight, sinuous, or aquiline. The retroussé, seen chiefly among women, is the underdeveloped, whereas the aquiline, seen chiefly among men, is the exaggerated form of the hyper-phylo-morph nose. Associated with this form of nose is the long, narrow face, and the long, high, narrow head. The distance from the external auditory meatus to the tip of the nose is greater in this form than in either of the others, and this projection of the nose to a pointed tip in association with the high, narrow forehead and pointed chin give the characteristic appearance called by the Australians in derision, "the hatchet-faced Englishman."

The most representative types of the hyper-phylo-morph nose in its primary form are found in northern Europe, Great Britain, and America, among the tall blonde Nordics, and this form of nose has been modified around the Mediterranean where it is extremely fine and thin. Its most exaggerated forms are to be seen among the Jews, Arabs, and Gypsies. It is found more or less modified in Asia and Africa along the course of four streams of infiltration. The most intense forms (the most perfect) are in southern Asia and northern Africa, the least intense in northern Asia and eastern Africa. The American Indians present a hyper-phylo-morph nose of an intermediate form between that of the extreme meso-phylo-morph and the primary hyper-phylo-morph. The characteristic hyper-phylo-morph nose dwindles in purity and frequency through southern Asia and northward through the hearts of the large islands of the Pacific among the inland tribes, except among the Tasmanians, Australians and Melanesians, to the inland tribes of the Philippine Islands, and eastward into Polynesia; through northern Asia into China and Japan, where in the latter place the nose is similar to that of the Mediterranean peoples; through northern Africa into the Soudan to the Guinea coast, and through eastern Africa to the Congo and along the south and east coasts up to the Guinea coast and the Congo again. The peoples who have this form of nose in greatest purity may be enumerated as follows: Danes and Scandinavians, North Germans, British, America whites in the United States and Canada, Spanish, Portuguese, some southern French and Italians, Greeks, Turks, Arabs, Jews and Gypsies. Those peoples among whom modified, yet fairly typical, forms are frequent are: East Indians, Iranians and Turanians, North and East Africans, Europeans other than those previously mentioned, Chinese, Japanese and Thibetans, Polynesians and Micronesians, and the inland tribes of the great islands of the Pacific, Java, Sumatra, Borneo, Celebes, and the Philippines.

The three forms of the nose may appear pure among any people, and in differentiating the three forms in any locality I use the terms hypo-onto-morph, meso-onto-morph and hyper-onto-morph because in every individual it may not be clear that the form of the nose is due to evolution—it may be developmental. The -onto-morph noses are not so strikingly different as the -phylo-morph forms, but in any case the hypo-onto-morph resembles the hypo-phylo-morph, the meso-onto-morph resembles the meso-phylo-morph, and the hyper-onto-morph resembles the hyper-phylo-morph.

THE NOSE OF THE JEW AND THE QUADRATUS LABII SUPERIORIS MUSCLE

ROBERT BENNETT BEAN

From the Medical Department, Tulane University

The peculiar position of the Jew for centuries may account for the origin of the Jewish nose. The shape of the nose depends upon inherent and extraneous influences. The latter do not concern us at present. Of the inherent influences, alterations in the bones of the head and face cause changes in the shape of the nose; increased vascularization of the nasal mucous membrane and the erectile tissues of the nose, as in continued excessive sexual indulgence, may alter the shape of the nose; and the muscles attached to the nose may change its form.

The quadratus labii superioris muscle has four parts, all of which center around the alae of the nose and the base of the upper lip, and from there they radiate towards the eyes in the shape of an imperfect fan. The two extremities of the fan are attached, the one at the root of the nose, the other to the ventral surface of the malar bone. The part of the quadratus muscle attached to the nose is called the angular head, which has two slips, one rising from the nasal bone and inserting into the cartilage and tissues about the ala of the nose; the other arising from the upper part of the nasal process of the maxila near the inner canthus of the eye and inserting into the skin and fascia at the base of the upper lip midway between the center and the side of the mouth. The angular head has been called the 'levator labii superioris et alaeque nasi muscle,' a term that expresses its action. The muscle slips pull the ala of the nose upward and backward, depress the extremity of the nose, and help to elevate the upper lip and deepen the naso-labial groove. The two remaining portions of the quadratus muscle are called the levator labii superioris and the zygomaticus minor, which form the infraorbital and zygomatic heads, respectively. They rise from the maxilla and malar bone beneath the orbicular muscle and are inserted into the skin and fleshy part of the upper lip near the corner of the mouth. They pull the upper lip upward and backward and deepen the naso-labial groove. Deepening of this groove gives an expression of sadness, which is intensified by sorrow or grief. Assisted by the great zygomatic muscle, and the caninus, the quadratus draws the tissues covering the chin upward and backward, pulls the corner of the mouth in the same direction and deepens the naso-labial groove. This sharpens the chin and makes it appear to tilt upwards in the form of a beak. The depression of the point of the nose tilts this member downward and gives it the appearance of an inverted beak. The mouth is at the same time drawn back, and the double beak becomes more emphatic.

The quadratus muscle is said to produce expressions of the face that indicate a great variety of emotions, all of which may be grouped as related to indignation. It is essentially the muscle of disgust, contempt, and disdain, which lead to scorn, acknowledging guilt. Discontent follows, with a snarl, sneer, and defiance; after which comes bitterness, and a menacing attitude, with pride. Indignation, anger, rage, and hatred rapidly succeed each other. This complex of emotions may be superseded by sadness, grief, or sorrow. That one small muscle group can express so many emotions is almost inconceivable, but upon intimate analysis the nineteen words used to enumerate the emotions expressed by the quadratus muscles are related, or proceed the one from the other in natural sequence.

The expression of the Jew is that which would result from very strong contraction of the quadratus muscle. The nose is depressed, and this is so marked that often an obtuse angle is made at the junction of the cartilage and nasal bones, which leaves the cartilage slanting very little and at times vertical. The nose of the Jew is large, and the depression of the tip increases the prominence of the bridge and adds to its apparent size. The ala looks pulled upward and backward, a furrow is seen around the ala, and the naso-labial groove is deep. The upper lip and the corner of the mouth appear pulled upward and backward, and the tissues of the chin are drawn, giving the beaked look. This characteristic is not well marked on all Jews, but is more emphatic on some than on others; it is also to be seen on those who are not Jews, but it is more pronounced on Jews than on other peoples, and that it is a Jewish feature cannot be doubted. Having become a recognizable characteristic, it was used in sexual selection. Those who showed it most strongly would be selected in marriage by the most orthodox, and would transmit a natural endowment to their offspring. Those who gave less evidence of it might marry outside of the race. In this way the feature became fixed, and it is as much an inheritance as any other characteristic. The peculiar position of the Jew for centuries may account for the origin of the Jewish nose.

PREPARATION OF MATERIAL FOR HISTOLOGY AND EMBRYOLOGY, WITH AN APPENDIX ON THE ARTERIES AND VEINS IN A THIRTY MILLIMETER PIG EMBRYO

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THREE FIGURES

The essential of a good course in histology or embryology is good material. Fresh human material should never be allowed to go to waste, but it may be at times very inconvenient to put it up in a variety of fancy fixing fluids.

Perhaps the best general cytoplasmic fixer is formalin of 10 to 20 per cent (4 to 8 per cent formaldehyde). If material so fixed is not soaked too long in alcohol of high concentration, it may be used as fresh tissue in special technique to show fats or mitochondria. In fact the formaldehyde alone makes unsaturated fats and lipoids less soluble in clearing fluids. On the other hand, if the washing in water is omitted, the structure of resting nuclei is well enough preserved for ordinary purposes.

Commercial formalin contains formic acid, which, although developing a more beautiful nuclear structure, may begin to cytolyse the more delicate cells before they are sufficiently fixed by the formaldehyde. This is especially noticeable in erythrocytes—haemolysis, or escape of haemoglobin, occurring in parts of the tissue. Furthermore, acids swell fresh white fibrous tissue. It seems worth while, therefore, to neutralize the formol, and this may easily be done by adding slack lime ($CaCO_3$) or magnesia, and filtering.

Doctor Ferguson first called my attention to the fact that kidney swells in many fixing fluids, whereas it is commonly supposed that the majority of tissues shrink a little. Death of isolated cells as seen under the microscope may be accompanied by swelling (cytolysis) or contraction. In every case, an increase in permeability to some substances occurs, but I found that during the early stages of cytolysis of the sea urchin's egg, it remains very impermeable to salts. Dead animal or plant membranes are more permeable to water than to dissolved substances, but apparently some living cells are impermeable to water. The Fundulus egg, if transferred from sea water to distilled water, does not burst, though it is certainly not capable of resisting the enormous osmotic pressure of its internal salts. Since I found this egg to be impermeable to salts, it must also be impermeable to water (it is permeable to kations, but for every kation that comes out, the electrical equivalent must go in). If such a cell became, on death, permeable to water, the osmotic pressure of its internal dissolved substances might cause it to swell. If a Paramoecium be killed by an ordinary fixing fluid, even though it be hypertonic, the protoplasm first coagulates, then the whole animal swells a little. This may be what happens to some tissue cells, and I found that it is not always prevented by the addition of 0.9 per cent sodium chloride to the fixing fluid. Therefore I supposed the swelling due to the osmotic pressure of some contained substance of large molecule, and experimented with the addition of cane sugar to neutral formol. By this means the cytolysis of adult convoluted nephric tubule cells is prevented, and the general fixation is good except that some nuclei may be slightly shrunken. This fluid may be used for all adult tissues and embryos, and is easily prepared as follows:

Formol	100–200 cc.
Cane sugar	20–40 grams
Slack lime ($CaCO_3$) or magnesia	about 1 gram

Water to make 1 liter.

If the shrinkage of a few nuclei is very objectionable use only 20 grams of sugar. This fluid has the advantage that tissues and embryos float in it and therefore do not become distorted.

If the whole kidney of a fetus be fixed in the above mixture or any other fixing fluid, the cells of the convoluted tubules will swell until they fill the lumen. This brings us to a well known point that is often neglected. Tissues should be cut into as thin slices or pieces as is practicable and the cells not injured in the cutting. Fetal tissues are especially delicate. They should be cut with a very sharp thin blade and lifted on the blade into the fixing fluid.

Many workers object to formalin because it "causes" a homogeneous appearance to protoplasm. The ultra microscope has shown that, aside from evident granules, living protoplasm is homogeneous, contrary to Bütschli and others. There are persons who now accept formalin for cytoplasmic fixation but say that it "does not fix nuclei well." Some structures may be seen in living nuclei. I have studied many nuclei with high powers and with the ultra microscope, yet I cannot decide what form of fixation corresponds most closely to the living structure. Both cytoplasm and nucleus of a living erythrocyte of a frog is homogeneous when examined in serum or uncoagulated plasma with the ultra microscope. Sooner or later bright points or clouds appear on or in the nucleus, but this is usually associated with change of nuclear form and is evidently due to injury.

Formaldehyde not only does not coagulate protoplasm but renders it more difficult to coagulate. It also makes lipoids less soluble in clearing fluids. However, I find an after-treatment with Müller's fluid or some other oxidising fluid necessary for the preservation of lipoids, the amount of oxidation necessary depending on whether mitochondria, myelin or fats are studied.

Ordinary staining depends on the fact that all protoplasm treated with acid, stains with acid dyes, whereas certain parts take also basic dyes. Many staining solutions contain free acid, but tissues stain more quickly if they are previously treated with acid. For this reason we put everything into the formol mixture and after a few hours transfer part of it to Bouin's fluid. This tissue is finally stained on the slide in haematin and eosin. The alum haematin lake is usually so strong that it stains in three minutes, but the eosin is so much diluted that twelve hours are required to stain and in this time smooth muscle stains less intensely than white fibrous tissue The acid in

Bouin's fluid causes the tissue to stain more brilliantly but if the fresh tissue is put into Bouin's fluid the blood in some of the vessels will be laked. Part of the material is transferred from the formol mixture to Müller's fluid and subsequently stained with iron hematoxylin to show the lipoids (mitochondria, etc.).

Ordinarily, the student is shown two dimensions of a piece of tissue or embryo, and left to imagine the third. Though whole mounts of chick embryos are handed out, cleared pig embryos, and blocks or thick sections of certain tissues are even more useful. For a solid mount, the object should be placed in a dish of balsam or damar dissolved in benzol and protected from dust until it evaporates down to sirupy consistency, then mounted in the usual way. By this means the necessity of rings or other supports to the cover glass is avoided, and drying out or great shrinkage prevented.

All of the solid mounts turn yellow with age, but a number of highly refractive fluids may be obtained that are colorless. These are listed, with their refractive indices, in Landolt-Bornstein; Behren's Tabellen; and Lee's Vade Mecum. The higher the refractive index the better, for if in any case a lower index is desired, this may be obtained by the addition of paraffin oil or xylol (or water in case of aqueous media). It may be noted here that, whereas the process of clearing in a mixture of oil of wintergreen (Gaulteria) and benzyl benzoate has been patented in Germany and is widely known under the name of the patentee, wintergreen was first used by Stieda in 1866, and the synthetic oil (methyl salicylate) recommended by Guéguen in 1898, and is noted in various books on technique.

Methyl salicylate is permanently colorless, and comparatively inexpensive, and ideal for a fluid mount. If rings are cemented on slides with shellac or liquid glue and allowed to dry, they are not loosened by the oil. Paper rings soaked in shellac or glue will do, but rings may be cut from lead pipe with an ordinary saw or a bone saw if the proper size of glass rings are not at hand. The shellac must be dry before adding the oil, which must be free from alcohol. I prefer glue.

If the tissue is hardened in alcohol, thick sections may be cut free-hand. Thick sections are often better unstained, especially if injected, and much detail may be made out by partly closing the diaphragm of the microscope. If stained with very dilute haematin containing much acid, connective tissue is colorless and cytoplasm nearly so, whereas nuclei may be readily distinguished. In this way blood vessels and glands in areolar tissue are caused to stand out sharply.

Whole mounts and thick slices are especially useful in embryology, and are a necessity unless one is contented with teaching the third dimension with models. The larger the embryo, the more attention must be paid to the clearing medium in order to distinguish internal structures. Methyl salicylate is admirable for pig embryos of all sizes and even for small fetuses. I found ethyl salicylate to be as good if not better, but it is more expensive. Canada balsam has about the same refractive index ($^{n}D = 1.535$) as methyl salicylate ($^{n}D = 1.536$), but darkens with age.

Embryos may be placed directly from absolute alcohol, benzol, xylol, toluol or chloroform into methyl salicylate, but in order to obtain the proper refractive index, the preliminary fluid must all be removed. This may be evaporated, or washed out with more wintergreen. Benzol is to be recommended because it is cheapest and evaporates out most easily. The evaporation may be hastened by an air pump, which also removes any air bubbles that may get into the specimen. These bubbles expand and are absorbed after the pump is disconnected, or by successive pumpings. An ordinary air pump will cause the benzol and air to boil out. A water-suction air pump (aspirator) will suffice but a float valve and safety bottle should be interposed between the pump and the specimen to prevent the back flow of water. An exhaustible desiccator is convenient for holding large embryos while they are being pumped out. If the cover is well ground, the oil will seal it sufficiently, and vaseline should not be used.

Most of the internal organs may be distinguished in unstained embryos by cutting down the light. The individual cells of mesenchyme, cartilage and blood may be seen; the cellular structure of the neural tube is indicated by radial striations and the larger nerves appear as bundles of fibers. Some organs in smaller embryos are made more distinct by staining with very dilute alum haematin containing a large amount of acid.

Even in quite small embryos, many of the blood vessels may be traced by the blood cells, and the large empty veins followed as cavities. However, with the smaller vessels this becomes more laborious than serial sections. On the other hand, the injection of small embryos for class use means quite an outlay of time. Therefore, it seemed necessary to find some way to fix the haemoglobin, and keep the vessels full, in order to distinguish the vessels by the color of the blood. I found that *the same method that prevents the cytolysis of nephric tubule cells prevents haemolysis.*

Living embryos are obtained, the amnion opened, the placenta squeezed to force the blood into the embryo, and the umbilicus tied or clamped. Artery clamps are too strong and pinch off the cord. (I made clamps out of wire (lower part of fig. 1) in order to avoid tying so many cords at the slaughter house. The clamp may be removed in half an hour and used again.) The embryo is dropped into the neutral-formol-sugar mixture described above, and left until thoroughly fixed. In case of a fetus, part of the skin should be torn off after the superficial blood vessels are fixed, to insure penetration of the formaldehyde. A hole may be made in the skull by slicing off a small piece tangentially or by a sagittal cut near (to the right of) the median plane. Large fetuses, unless skinned completely, will have to be scraped to remove the pigment layer.

Transfer the specimen after washing, or directly, from the fixing fluid to alcohol of about 70 per cent. After they have hardened in 80 or 95 per cent alcohol it is well to split the large specimens by a sagittal cut a little to the right of the median plane with a very thin bladed knife. The dehydration with higher alcohols should be slow enough to prevent shriveling.

By this method the blood retains its color, and although it does not take the place of injection, it is a great help to the student. I have inserted three figures to show what can be seen in such specimens.

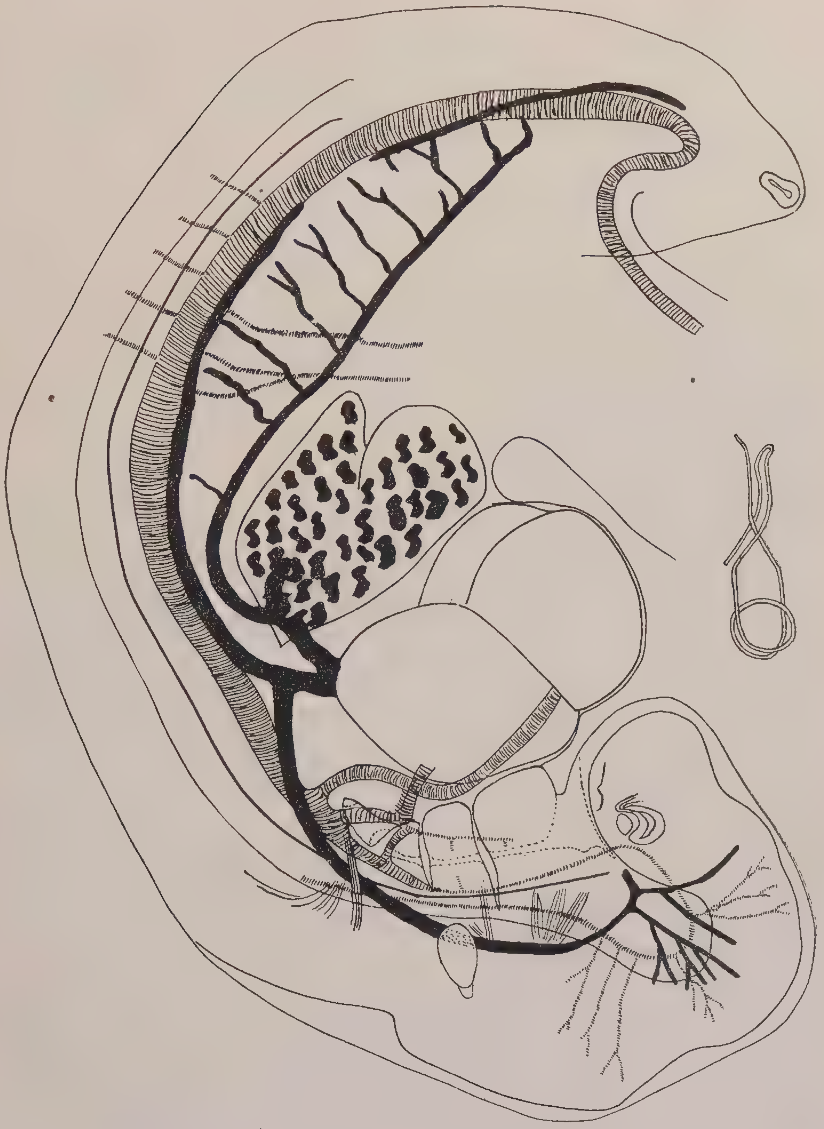

Fig. 1 Left half of a pig embryo 7 mm. long after clearing. The veins are black, the arteries cross-striated, the 5th, 7th, 8th, 10th and 11th cranial nerves are longitudinally striated, the notochord is represented by a heavy line and the fore gut by a dashed line. The sinuous line ventral to the embryo represents a wire (partly open) clamp used in clamping the umbilicus.

Figure 1 represents a pig embryo about 8 mm. long. The nerve tube, fore gut, mesonephros, liver, heart, eye and ear are clearly seen. The arterial system and part of the cardinals and subcardinals can be distinguished. The notochord is distinct, and the 5th, 7th, 8th, 10th, and 11th cranial nerve roots can be made out. Figures 2 and 3 are described in the appendix.

I have prepared hundreds of pig embryos and fetuses in this way, and also injected many with india ink and cleared them in wintergreen oil. A completely injected fetus can only be studied in comparatively thin (freehand) sections. Various degrees of partial injection are very useful to show the larger vessels, but these may be seen in the uninjected fetuses. The left side of an uninjected fetus which has been cleaved a little to the right of the median plane, will show the general circulation, except in the liver. The larger vessels in the liver may be seen by removing the lateral portions and passing a strong light through the remainder (an arc light is excellent), or the liver may be removed and cut into slices. In injected specimens the liver is hopeless.

I washed with alcohol the blood out of the vessels of a fetus 4 inches long and cleared it in wintergeen oil, then injected it with mercury. This method has the advantage that the extent of the injection may be watched and controlled.

The injection may be limited by using a coarse granular pigment that will not go into the capillaries. A gelatine mass is not absolutely necessary to hold the pigment. A light colored opaque pigment has the advantage that it may be seen by transmitted or reflected light.

The arteries may be injected and the haemoglobin fixed in the veins, giving handsome specimens. If it is desired to show only the injection, no formalin should be used. Much of the haemoglobin may be dissolved out by putting the fresh specimen into weak alcohol or alcohol and acetic acid. All of the haemoglobin may be removed with dilute acetic acid provided an injection is used that is not affected by this acid.

APPENDIX

ON THE ARTERIES AND VEINS IN A 30 MM. PIG EMBRYO

The method of fixing the haemoglobin and clearing in wintergreen oil to show the course of the vessels has been especially successful in case of pig embryos of about 30 mm. length Figures 2 and 3 show the larger vessels of the median plane and left side of one of them. The courses of most of the vessels approach the type of the adult pig and show distinctions in topography from those in man. The common carotid artery and (right) innominate artery arise from a common trunk, the brachiocephalic artery. The posterior inferior cerebellar artery arises from the basilar instead of from the vertebral.

Notwithstanding the great development of the vena cava, the left posterior cardinal is of considerable size. The right cardinal (not figured) is smaller. The thoraco-epigastric vein is divided into two parts, one of which drains anteriorly into the internal mammary.

The vessels of the limbs could not be completely followed, but enough was seen to demonstrate that they differ very much from those in the adult.

Besides the vessels, the mouth cavity, brain, eye, endolymphatic labyrinth, lungs, mesonephros, kidney, testis and penis are outlined in the figures.

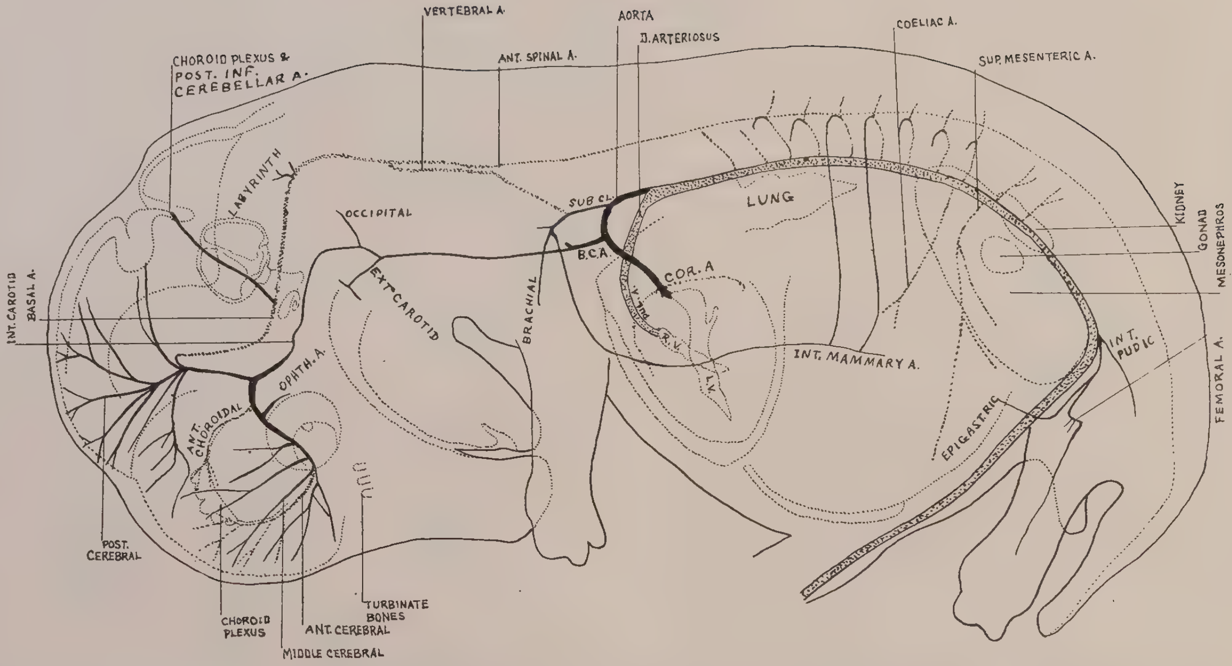

Fig. 2 The arteries of median plane and left side of a pig embryo 27 mm. long after clearing. The arteries farthest from the observer are stippled. The musculo-fibrous coats are not represented, and some of the arteries are so contracted as to almost obliterate the lumen. *B.C.A.*, brachio-cephalic artery; *COR.A.*, coronary; *SUBCL.*, subclavian; *PUL.A.*, pulmonary; *OPHTH.A.*, ophthalmic; *LV.,RV.*, cavities of left and right ventricles.

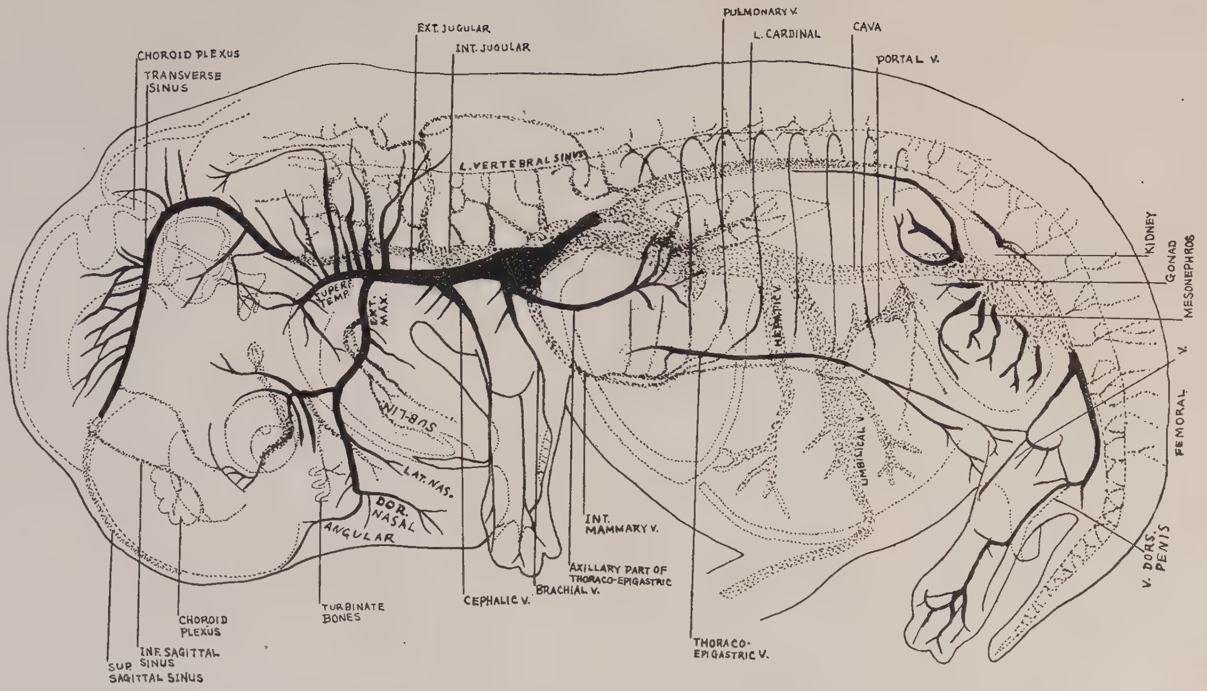

Fig. 3 Veins of median plane and left side of a pig embryo 27 mm. long after clearing. Each vein is represented by its lumen only, but some have been purposely made smaller for clearness in the figure. The representation of the veins between the mesonephroi is somewhat diagrammatic.

A NEW TECHNIQUE IN THE FIXATION AND STAINING OF NERVE TISSUE

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The following work was undertaken with the view to obtaining a stain for nerve tissue, which might be suitable for both histologic and pathologic purposes. Experimentation with numerous stains and staining methods, gave me negative results with tissues fixed by the ordinary methods (alcohol, formalin, Zenker's, Müller's, Weigert's fixatives, etc.). I turned my attention, therefore, to the development of a fixative which besides giving the desired results, will also minimize the time element.

Several years ago I became impressed with the excellent preservation of color, and comparative softness of sugar-cured meats. Manifestly sugar or its cleavage products act on the tissues so as to prevent certain decompositions. Various preserved meats bought in the market, dehydrated in alcohol and embedded in celloidin gave peculiar variations in the staining reaction with eosin and hematoxylin, but in almost all of these the microscopic elements were very much dulled. However, since the color preservation and softness in sugar-cured meats, was not to be disputed, I began adding various sugars to the fixatives used for fixation. The best results were obtained with nerve tissues. As a result of experimentation the following solution which consumes comparatively little time, before the tissue is ready for examination, was devised

Dextrose	5 grams
Lactose	2.5 grams
Levulose	2 grams
Formalin	10 per cent—10 cc.
Water (preferably distilled)	to 100 cc.

This solution is preferably made fresh, though a concentrated mixture of dextrose and lactose may be kept on hand. My experience with this fixative made up in bulk has been unfavorable; it will keep, however, for about a week.

Pieces of nerve tissue from $\frac{1}{3}$ to 1 cm. in thickness are fixed for twenty-four hours, the fluid is then poured off, and pieces put in fresh solution from one to eight days, depending on the thickness of the tissue. Better results may be obtained if several changes of the fixative are made. At any time, the occurrence of cholesterin crystals in the fixative, is evidence that the tissue is ready for dehydration. Moderate warmth (summer or heated room), 72° to 85°, is almost an essential in obtaining perfect results. The pieces of tissue are brought directly from the fixative into 95 per cent alcohol, thence into absolute alcohol, and finally into equal parts of absolute alcohol and ether, and embedded in celloidin (occasionally it is found best to omit the ether). The latter procedures being the same as are employed universally for celloidin embedding. With thin pieces of tissue, this ought not to take over five days.

STAINING METHOD I

Sections are cut in 80 per cent alcohol and transferred directly into the original fixative and allowed to remain for several hours (best effects obtained after twelve hours) and are now placed in Delafield's hematoxylin one part and distilled water two parts. They are allowed to stay in this stain from five minutes to twenty-four hours, depending on the depth of color desired and the strength and age of the hematoxylin. The sections are then washed in several changes of *tap* water, and stained in an alcoholic solution of eosin, from one to ten minutes, washed n water, dehydrated in several changes of 95 per cent alcohol, cleared in carbo-xylol, or oil of origanum, or cresote and mounted in xylol-balsam or balsam. If too dark, they may be decolorized in acid alcohol, before the eosin stain is used. My best results were obtained with tissues that had been decolorized. This method stains all cells blue, brings out clearly the Nissl's granules and stains the nuclear wall and nucleolus. Axis cylinders and neurilemma sheaths are stained a light blue. The neuroglia processes take the eosin stain, but their nuclei are stained dark blue. The dendritic processes are followed for quite a distance. Chromatolysis, pyknosis, neuroglia increase and old degenerations of the axis cylinders are easily demonstrable. Ordinary inflammatory processes are most readily brought out. The myelin sheath is not stained or but faintly tinged.

METHOD II

The specimen is treated the same as in Method I but the sections instead of being counterstained with eosin, are decolorized in equal parts of Weigert's decolorizing agent (borax 2, red salt of potassium ferricyanide 2.5, distilled water 200) and distilled water from five minutes to several hours. They are then washed in several changes of water, dehydrated in alcohol, cleared and mounted. This gives an exact replica of the picture obtained with the Weigert medullary sheath stain but has the additional advantage of staining the motor cells a distinct brown and other cells a rather deep brown. The nuclear wall and nucleolus are a brownish black. The myelin sheath is stained a faint blue.

METHOD III

The sections are cut in 80 per cent alcohol, washed in one water and put in 5 per cent solution of ferric chloride from fifteen minutes to several hours; washed in several changes of water and stained in equal parts of Delafield's hematoxylin and water from a minute to half an hour. They are then washed in several changes of water, decolorized (5 to 30 minutes) in Weigert's decolorizing agent or equal parts of sweet spirits of ether and water, again washed, dehydrated, cleared and mounted. This method gives almost the same results as Method II.

Good results may be obtained with the staining methods here enumerated even though the tissue has been fixed in formalin for some time, providing the pieces of tissue be run through the sugar solution in the same manner as if they had been fresh.

To recapitulate, the afore-mentioned fixative gives good histologic and pathologic pictures with the ordinary eosin-hematoxylin stain. The use of the method admits of a great saving in time, since sections cut from the same block can be stained with the eosin-hematoxylin, for cellular study including Nissl's granules and with hematoxylin followed by decolorization for focal degenerations or histologic demonstration of the axis cylinders and neuroglia. In allowing myself great latitude of time in fixing, mordanting, staining and decolorizing, I have been able to obtain much variation in nuance of color. A standard can be fixed by the individual worker.

For the ability to carry on these investigations I am indebted to Prof. B. H. Stone, Director of the State Laboratory of Hygiene, and Prof. T. S. Brown for valuable suggestions, assistance and an abundant supply of material, and to the Dean as well as the Trustees of the College, for their liberality.

BOOKS RECEIVED

AN ATLAS OF THE DIFFERENTIAL DIAGNOSIS OF THE DISEASES OF THE NERVOUS SYSTEM. Analytical and semeiological neurological charts. Henry Hun, M.D., professor of the diseases of the nervous system in the Albany Medical College. 290 pages including Index, 1913, $4.00. The Southworth Company, Troy, N. Y.

ARBEITEN AUS DEM NEUROLOGISCHEN INSTITUTE (k. k. österreichisches interakademisches Zentralinstitut für Hirnforschung) an der Wiener Universität. Unter Mitwirkung von Priv. Doz. Dr. Otto Marburg herausgegeben von Prof. Dr. Heinrich Obersteiner. XX Band, 1 Heft, mit einer Tafe- und 19 Abbildungen im Text (154 pages), Ausgegeben im November, 1912. Leipzig und Wien, Franz Deuticke.

THE DEVELOPMENT OF THE HUMAN BODY, a manual of human embryology, J. Playfair McMurrich, A.M., Ph.D., LL.D., Professor of Anatomy in the University of Toronto, formerly Professor of Anatomy in the University of Michigan, fourth edition, revised and enlarged, with 285 illustrations (several of which are in colors), 496 pages including Index, 1913, $2.50. P. Blakiston's Son and Co., Philadelphia.

RECOGNITION OF MEMBERS OF THE SOMATIC MOTOR CHAIN OF NERVE CELLS BY MEANS OF A FUNDAMENTAL TYPE OF CELL STRUCTURE, AND THE DISTRIBUTION OF SUCH CELLS IN CERTAIN REGIONS OF THE MAMMALIAN BRAIN

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While studying the nuclei of the human diencephalon my attention was attracted to certain cells in the hypothalamus which could scarcely be distinguished from the typical cells of the peripheral somatic motor neurones. Further study revealed the presence in the hypothalamus of other cells which exhibited merely a slight indication of such structure, and between these two extremes, cells were found which showed every gradation of motor structure. I was led to attach importance not only to those cells in which the resemblance to peripheral motor cells was marked but also to those of less characteristic structure, on account of the following fact: in the other subdivisions of the diencephalon, as well as in the majority of cell groups of the hypothalamus, no single cell was found which showed the slightest trace of such structure. These cells have been found by me also in the monkey, lemur, and cat, and the statements in this article apply to all these animals as well as to man. The material studied was fixed in 95 per cent alcohol and embedded in paraffin; the sections were stained in a 1 per cent aqueous solution of toluidin-blue, differentiated in 95 per cent alcohol, dehydrated in absolute, cleared in xylol, and mounted in canada balsam.

It will be necessary to explain the term 'somatic motor cell' as employed in this article. In the mammalian brain two distinct series of motor cells exist. Those supplying smooth muscle and heart muscle are known as visceral or sympathetic, while all those supplying striated muscle are termed in this article 'somatic.' Accordingly the somatic motor cells would thus include not only

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the ventral group of motor nuclei of the cranial nerves, but also the lateral group, consisting of the motor nuclei of the following cranial nerves: spinal accessory, vagus (nucleus ambiguous), facialis, and trigeminus. These lateral motor nuclei are considered somatic and are classed with the ventral motor nuclei on account of the following reasons:

1. The cells of these nuclei supply muscles which both structurally and functionally cannot be distinguished from the muscles supplied by the ventral group of motor nuclei and by the anterior horn cells of the spinal cord, and which must therefore be considered somatic.
2. The axones of these cells run directly to the muscles as in the case of the ventral group of motor nuclei.
3. The cells of these nuclei cannot be distinguished structurally from those of the other somatic motor nuclei.
4. Two visceral (or sympathetic) motor nuclei in the mammalian brain have been definitely determined, namely, the so-called dorsal motor nucleus of the vagus and the Edinger-Westphal group of the oculomotor nucleus; the cells of these visceral motor nuclei may be readily distinguished structurally from the somatic motor cells. So fundamental is the difference in structure between the visceral and somatic cells that in a five-months human embryo there is a marked difference between the cells of the dorsal motor (visceral) vagus nucleus and the cells of the neighboring hypoglossus nucleus.

The lateral group of motor nuclei of the cranial nerves of mammals belong, therefore, both structurally and functionally to the somatic motor nuclei, and not to the visceral, from which they can be clearly distinguished both in structure and function. Although the origin of the muscles supplied by these lateral nuclei would indicate that both they and the nervous elements supplying them might be visceral, this supposition is conclusively disproved by the function and structure of such muscles and the nerve cells which innervate them; the visceral origin of these lateral nuclei is revealed in adult mammals solely through their position. I do not desire to attack the division of the nervous system into somatic and visceral motor components; on the contrary I consider this distinction fundamental and highly desirable. But from the standpoint of structure and function this distinction does not always hold. It is essential that we view the nervous system from many standpoints, and it is accordingly highly undesirable that a classification be employed which tends to obscure the question under consideration. The division herein employed is unfortunate in that it fails to take into account the difference between the somatic and visceral motor columns, while the other classification is open to the criticism that it terms visceral structures that have ceased to be visceral. This matter needs more discussion, and for the present I shall content myself with having pointed out what I understand under the term somatic motor nerve cell.

Certain cells whose axones end in relation to the peripheral somatic motor cells have been generally recognized as motor, and the similarity in structure between these two classes of motor cells has been noted, although not especially emphasized. The structure of such cells as revealed by toluidin-blue sections of alcohol-fixed, paraffin-embedded tissue, cannot always with certainty be distinguished from that of the peripheral somatic motor cells, except that these cells show a tendency towards an exaggeration of the typical structure of the peripheral cells; thus although the peripheral motor cells are large, the cells of the neurone immediately superimposed are often even larger. These cell groups will be discussed later. The structure of both of these classes of somatic motor cells is well known, but in addition to the large size and the sharply polygonal form another characteristic should be noted, which is common not only to these cells, but also to certain other cells which I believe to belong to the somatic motor chain, namely, the chromophilic substance outside of the cell nucleus is not scattered throughout the cell in the form of fine granules, nor is it grouped together in indefinite masses, but when observed under rather low magnification (100 to 200 diameters) is seen to be arranged in definite, relatively large granules which have a relatively smooth contour. In other words the chromophilic substance is arranged in definite bodies. This fact has been recognized by Jacobsohn, who has formulated the following law: "Je mehr sich der Nervenstrom von der sensiblen Endstation des Zentralnervensystems der motorischen Endstation desselben nähert, um so mehr sich die Structur des Protoplasmas der zu passierenden Nerven-zellen aus einer feinkörnigen in eine grobschollige verwandelt." It was Jacobsohn who first pointed out in the above law that the characteristic structure of motor cells depends upon the arrangement of the Nissl granules; moreover Jacobsohn has been able to point out the fact that certain cell groups, whose function had been unknown are composed of cells whose structure compels us to recognize them to be motor. He has thus been able to advance our knowledge of the function of certain cell groups through histological evidence, and has emphasized the interdependence of cell structure and cell function. According to Jacobsohn's law, however, there is a gradual transition of cell structure from the sensory to the motor cells so that it would be impossible to separate these two classes of cells structurally; he has therefore for the most part termed as motor only such cells as possess a structure almost identical with that of the peripheral somatic motor cells. Since I am about to suggest certain modifications of Jacobsohn's law which I consider essential, I should like to state with all emphasis that his work is of the greatest importance; it was from him and in his laboratory that I learned to associate cell structure with cell function, and learned to recognize what was really essential in the structure of motor cells. It gives me sincere pleasure to state that without this fundamental work of Jacobsohn's the results of my own work, which I shall now take up, would have been impossible.

As to whether Jacobsohn's law applies to the afferent chain I cannot positively state; in fact, as far as my experience goes (and I have made no careful study of this problem) I have never seen evidence that would support it. Without raising the question as to the existence of a transition in cell structure of the afferent chain, I must state that I am thoroughly convinced that there is no gradual transition of cell structure from the sensory cells to the cells of the motor chain, but at a certain point there is a sudden marked change in structure to the motor type, which becomes more pronounced towards the peripheral end of the efferent chain, and reaches its maximum in the last two (peripheral) cells of the series. As an instance of this sudden change I may call attention to the great change in structure between the Purkinje cells and the cells of the dentate nucleus and more especially the cells of the roof nuclei of the mammalian cerebellum. The Purkinje cells show absolutely no trace of motor structure, while the cells of the internal nuclei of the cerebellum (which we know to be efferent) are unmistakably motor, in that they have the coarse granules found only in motor cells. I do not wish to raise the question whether the Purkinje cells should be considered afferent or efferent, but the fact remains that so far as their structure goes they do not belong to the efferent series, while the next cells in the arc belong from every standpoint to the efferent series.

While the afferent chain is complicated by the fact that it arises in different cases from sensory end organs of widely different nature, the somatic motor chain always ends in cross striated muscle. The peripheral motor neurones therefore constitute a definite functional group, and this specialization of function corresponds in mammals to a definite type of cell structure. With the peripheral motor neurones certain others in the efferent chain are associated in transmitting impulses to cross striated muscle, and all cells which are thus definitely set aside exclusively or at least primarily for this specific function are characterized by a common fundamental structure, and while differing from one another in structure may be as a class identified microscopically from all other cells (whether afferent, correlative, or efferent) which do not share in this function. This fact may be expressed in the following law:

There is no gradual transition in structure between the cells of the afferent and motor chains, and there is no indication of the beginning of motor structure in afferent cells. Those cells in the efferent chain whose function consists exclusively or primarily in conducting impulses through the chain to cross striated muscle, or between motor centers, are characterized by a common structure, which differs according to the position of the cell in the motor series. The cells composing this functional series may be recognized microscopically, *chiefly through the arrangement of the extranuclear chromophilic substance in relatively coarse granules.* At present I am unable to state whether the less characteristic motor cells, which when present at all in a motor series are situated at the central end of the chain, are exclusively motor in function or whether their less characteristic structure is the expression of a function only partly motor; the latter view seems more probable. It is impossible to state just why there should be a change to a definite type of cell structure at the point where the nerve impulse enters upon a definite, well defined, specialized pathway to the motor end station (including of course correlating paths between motor centers), but it is certainly far from improbable that the intracellular activities concerned in such neurones are of a different nature from those of cells which are concerned in receiving various kinds of incoming sensations and correlating these with one another and with sensations previously received. It has already been pointed out that a morphologically efferent neurone may be concerned in such essentially sensory functions, and that therefore the term efferent is not necessarily synonymous with the term motor (in a structural and functional sense).

REASONS FOR BELIEVING THE EXISTENCE OF A FUNDAMENTAL TYPE OF STRUCTURE PECULIAR TO CELLS OF THE SOMATIC MOTOR CHAIN

1. Not only is the structure of all peripheral somatic motor cells practically identical, but their structure is scarcely to be distinguished from that of those cells whose axones end in relation to them. This is a most important point, since it shows the closest relation between function and structure in both of these series of cells. Examples of cells whose axones end in relation to peripheral somatic motor cells are the following: (a) the large pyramidal cells of the anterior central gyrus giving rise to the cortico-bulbar and cortico-spinal tracts; (b) the cells of the motor portion of the red nucleus, giving rise to the rubro-spinal tract; (c) the motor cells of the anterior quadrigeminal body, from which arises the tecto-spinal tract; (d) the cells of Deiters nucleus, whose axones constitute the vestibulo-spinal tract. Every cell which

stands in this relation to a peripheral somatic motor cell and whose function is primarily motor shows without exception this characteristic structure. The term 'primarily motor' is used to exclude such essentially sensory cells as might occasionally be involved in a simple reflex; of course their essential function is receptive and hence the radically different structure.

2. Not the slightest indication of motor structure exists in cells which are known to be either afferent or concerned in correlating sensory impulses.

3. Certain cell groups are known to constitute a portion of definite somatic motor paths, although situated more centrally in the motor chain than the two peripheral neurones referred to above. I have observed in the mammalian brain that whenever a cell has been proved to have such a functional relation its structure is fundamentally similar to that of the more peripheral motor cells, and although less characteristic than the structure of the typical motor cells is fundamentally different from that of those cells which are known not to form part of such a somatic motor chain. Such cells compose the dentate and roof nuclei of the cerebellum, which are known to be efferent, and their structure is in marked contrast to that of the cells of the cerebellar cortex, and these are known not to be efferent. Another cell group which I have observed to possess motor structure is the nucleus of the posterior commissure, which sends at least some of its fibers into the posterior longitudinal bundle, a motor correlation system.

4. It has thus been shown that not only the peripheral motor cells and those cells whose axones end in relation to such peripheral cells have practically the same structure, but also a fundamentally similar (although less characteristic) structure is revealed in those cells further removed from the periphery whenever these cells have been shown to be at least primarily concerned in transmitting impulses through the somatic motor chain. Therefore, so far as our knowledge of the function of the different cell groups extends, it has been shown that a fundamental similarity of function is always accompanied by a corresponding fundamental similarity of structure. There remain certain groups

of cells showing the motor structure whose connections are unknown; if this were not so the correlation of a definite type of cell structure with a definite function would be of little practical importance. Certain of these cells are so typical in structure, which is that of so many cells whose function is known to be motor, that no serious doubt as to their nature remains; such cells are found in the formatio recticularis of the brainstem and of the hypothalamus. In addition to these typical cells other cells of unknown function occur in which the motor type of structure is less typical; the distribution of some of these cells will be considered later in this paper. The reasons for believing these less typical cells motor are as follows: first, their structure is as typical as that of certain cells known to be motor (for example, the cells of the internal nuclei of the cerebellum). Then these cells may occur together with typical motor cells and may show many grades of transition to these typical cells. Moreover these less typical cells may be traced continuously into regions in which occur typical motor cells. And finally regions known to be sensory (cerebellar cortex, thalamus, metathalamus, epithalamus) are conspicuous by the absence of any cells whose structure resembles in the least the fundamental structure common to all somatic motor cells.

THE DISTRIBUTION OF SOMATIC MOTOR NERVE CELLS IN CERTAIN REGIONS OF THE MAMMALIAN BRAIN

In the mammalian hypothalamus two groups of motor cells have been described by me. A small group of cells lies between the medial and lateral nuclei of the corpus mammillare, and I have named it, accordingly, 'nucleus intercalatus corporis mammillaris.' I regard this cell group as motor although the cell structure is far removed from that of the peripheral motor cells. The other motor group I have described under the name of 'substantia reticularis hypothalami,' which, as previously stated, contains not only typical motor cells, but also transition types to cells of much less characteristic motor structure; the substantia reticularis contains cells also which are probably not motor, but by far the greater number of cells of this cell group are of motor structure. The substantia reticularis of the hypothalamus is continuous caudally with the typical motor cells of the anterior quadrigeminal body and those of the substantia reticularis which extends throughout the greater length of the brainstem.

Between the cells of the oral portion of the substantia nigra I have described in man certain other cells which reach far laterally into the pes pedunculi and extend further oral than the cells of the substantia nigra. These cells are smaller and more sharply polygonal than those of the substantia nigra, and in man contain no pigment; they contain definite, relatively coarse Nissl granules and are definitely motor in structure. Formerly, while studying them in man, I was inclined not to separate these cells sharply from those of the substantia nigra, but upon studying them in other mammals (in which the cells of the substantia nigra are not pigmented) the difference between these two groups was striking. I formerly considered with Jacobsohn the cells of the substantia nigra in man to be motor, assuming that in most of the cells the motor structure was concealed by pigment but was revealed in the small-celled group. Study of other mammals, however, has shown this to be erroneous and I no longer consider the cells of the substantia nigra motor. The small cells above referred to are on the contrary definitely motor in structure, and therefore must be sharply distinguished from the substantia nigra. The division of the substantia nigra into a pars compacta (pigmented in man) and a pars reticularis (small, unpigmented cells) as adopted by some authors (Sano, Friedemann) is unsatisfactory, since it implies that the small cells are pigmented, although this is not true even in man; moreover the division is purely topographical, and does not imply a difference in cell type, nor is it even possible to separate the two types of cells by dividing the whole cell mass into a compact and a reticular portion. It is therefore desirable to keep in mind the difference in structure between the cells of the substantia nigra and the small motor cells of the group orolateral to it, and accordingly I suggest for this group the name 'nucleus intrapeduncularis,' which implies the tendency of the cells to push out into the pes pedunculi. These cells are described and illustrated in my monograph on the human diencephalon under the name of "kleine Zellen der Substantia nigra" (Sn′).

Another group whose cells show the motor type of structure is the globus pallidus of the lenticular nucleus. The motor type of structure in these cells is not striking, yet it is undoubted, and such as is not found in the cells of any sensory group. The contrast between these cells and those of the putamen is sharp, since the cells of the putamen reveal not the slightest tendency towards the motor type. Accordingly the lenticular nucleus is clearly separated into a medial motor group, and a lateral sensory group. I have been able to trace a continuity between the motor cells of the substantia reticularis of the hypothalamus and the cells of the globus pallidus; this fact is all the more significant when we recall that I have already shown a continuity between the motor cells of the substantia reticularis hypothalami and the motor cells in and near the anterior quadrigeminal body and in the substantia reticularis of the brainstem. I do not mean to state that the cell type of the substantia reticularis passes unaltered into the globus pallidus, but I do mean to state that there is a continuity of cells, and that both cell types are of a fundamentally motor structure. My study of this region has not as yet been sufficient to permit me to state whether a transition of cell type occurs.

In the study of the nervous system the value of an accurate knowledge of the cell structure of different cell groups has been underestimated. Histological subdivisions of the nervous system have been based largely upon a splitting up of the gray matter by fiber masses, and the result is for the most part a purely topographical subdivision; whenever the cell structure is noted the information is used to distinguish the cell group topographically rather than to connect this structure with some function. This disregard of cell groups of different structure occurring in the same region often seriously affects the results of experimental-anatomical and pathological observations, in which the origin and end of fiber tracts are noted without regard to the type of cells from which they arise or around which they end. Information which thus disregards the cell structure may of course be valuable, but it is far from satisfactory. Fortunately this neglect of cell structure does not apply to all the experimental work which is appearing, and it is most fortunate that much recent work, especially from the laboratories of von Monakow and van Gehuchten, includes a careful histological study of the cell groups of the regions involved. But experimental determination of the origin and end of fibers is in many regions of the central nervous system extremely difficult if not impossible, especially in mammals and above all in man. In such cases too much should not be expected from comparative anatomical studies, since the knowledge of a simpler mechanism can give only a general knowledge of a more complex one, and not the actual connections of specific neurones. It is in such cases that we must rely upon the principle that cell structure is an indication of cell function. For instance no one would question the presence of smooth muscle in a region where it was previously not known to exist if the microscopic picture revealed the presence of the definite structure known to be characteristic of such muscle; no evidence could be more conclusive, and the extent of distribution of this tissue could be shown in a manner absolutely impossible by experimental methods. While the function inherent in smooth muscle cells is always the same these cells may be so situated that the ultimate result of the contraction may be different; the ultimate function of the smooth muscle in the walls of the intestine is different from that of muscle in the walls of blood vessels. While in the case of such a tissue as smooth muscle its distribution will often reveal at once its ultimate function, this is not always so easy in case of nervous elements; the position of a group of motor cells does not make it evident whether they supply flexors or extensors, and this ultimate function must be determined first experimentally. Just so there is and should be no indication in the structure of the cells from which the fibers of the pyramidal tract arise as to whether these fibers end in relation to anterior horn cells or the motor cells of one of the cranial nerves. It is accordingly essential that we connect cell structure merely with the functional activities inherent in the cell itself, regardless of the actual position of any cell to which the first cell might send its axone. Where there is sufficient evidence we may go further and conclude from the structure of a cell that it not only sends impulses to a cell of a definite type, but also receives impulses from a definite type of cell; this is possible in the somatic motor chain.

I have shown that the members of the somatic motor chain may be recognized by their structure. When one recalls the great difference in structure of other cell groups in the mammalian brain and that homologous groups, often of the same definite cell structure, occur in different animals, it is evident that the whole of the central nervous system is far from being a simple switchboard composed of functionally similar elements, whose activities depend merely upon connections; that such indifferent cells exist in the central nervous system is probable. But from the evidence of the other tissues we are forced to the conclusion that whenever a definite type of cell structure occurs it is the indication of a definite function inherent in the cell. Just what the meaning of a definite type of cell structure is we do not know. To what extent (if at all) is it dependent upon the capacity of the cell to receive impulses of definite character, and to what extent does this structure indicate the ability of the cell to send out an impulse of definite character? The effect upon the structure of the cell which might be caused by frequent or infrequent use, by the length of its axone, by the volume of its discharge should and can be determined, and such quantitative factors should eventually be distinguished from those of a purely qualitative nature. Even if all the factors involved in producing cell structure should be shown to be quantitative (which I by no means consider possible) the cell structure would still have a meaning, especially since it is not transitory, but inherent in certain definite cell groups, and in homologous cell groups in different animals. The distinctive fundamental type of structure of the members of the somatic motor chain proves beyond doubt that even if this peculiar structure is due merely to the volume and frequency of the discharge it is confined to cells which stand in a definite relation to striated muscle, and is not found in other cells however much the volume and frequency of their discharge may vary.

An important field is open to students of the central nervous system in studying the cell structure of different cell groups, and in correlating a definite structure with a definite cell activity wherever this is possible; by this means we may hope eventually to decide the function of cells not accessible to experiment, just as is possible in other portions of the body; in case of the somatic motor cells this is already possible. In addition the determination of cell structure is invaluable in recording the extent and position of a functional center which has been experimentally determined, since without a knowledge of the type of cell involved the location of the center would be purely topographical and therefore inexact, especially in an animal of another species.

It is important to note the fact pointed out by Jacobsohn ('10) that a definite type of cell structure becomes evident and increases in its distinctiveness according to the extent to which this cell group becomes associated with a certain definite function. Accordingly we should expect to find and do find the most distinctive types of cell structure in cell groups which are phylogenetically old and in adults of those animals which stand highest in the phylogenetic series, since here we find the greatest specialization of function. Jacobsohn points out that the motor cells of the anterior horn show a loss of distinctiveness of structure as one descends phylogenetically, and that in fishes the cell protoplasm appears at low magnification almost homogeneous; in other words there is no trace of motor structure. My experience reaches only from man to the cat, but even within this relatively limited field I have been struck with the decreased definiteness in the structure of motor cells in the lower animals. If this is true for such phylogenetically old cell groups as the motor nuclei it is much more apparent in phylogenetically recent regions, such as the thalamus (in the narrower sense); after studying the relatively well differentiated cell types of the human thalamus, the study of the thalamus of the cat is most discouraging, for the different cell types approach one another so closely as to make a separation most difficult.. I cannot emphasize too strongly the fact that for the study of the structure of different cell groups by far the best material is the adult human brain; here is found a sharpness and definiteness of structure wanting in other forms. We cannot hope to find distinctive structure in a cell whose function is not specialized. Of course a nerve cell can have a special function before this function has visibly modified the cell structure, just as protoplasm is contractile before it is arranged into a form of cell especially adapted for this purpose with the characteristic structure of the muscle cell. One might object that the motor cells of the spinal cord in fishes are functionally specialized without having the characteristic structure found in mammals, and that this structure is therefore not essential to a definite specialized motor activity. This is of course true, but without raising the question as to whether this difference in structure corresponds to any difference in the nature of the motor impulse or whether it is merely an evidence of a more perfect intracellular mechanism for liberating such an impulse, we must recognize the fact that in the higher animals such an association of structure and function exists and should be utilized in working out the mechanisms of the central nervous system.

CONCLUSIONS

1. The cells of the visceral (or sympathetic) motor centers of the mammalian brain have a structure different from that of the cells of the somatic motor chain.

2. The lateral group of motor nuclei of the cranial nerves (XI, X, VII, and V) are from a functional and structural standpoint somatic, since they are composed of cells whose structure is identical with that of the cells of other somatic motor nuclei, and since they supply muscles which cannot be distinguished from other somatic muscles either in structure or function.

3. Those nerve cells in the mammalian brain which belong to the somatic motor chain, i.e., those cells whose function is exclusively (or at least primarily) to transmit impulses to striated muscle or between different motor centers, are characterized by a fundamental similarity of structure, which differs according to the position of the cell in the motor chain. Such cells can be recognized by their structure with the use of comparatively low powers of magnification (100 to 200 diameters).

4. No trace of this structure is present in cells outside the motor chain, i.e., cells which are concerned in receiving and correlating incoming impulses.

5. The hypothalamus is the only portion of the diencephalon which contains somatic motor cells.

6. The substantia reticularis hypothalami contains cells which show various degrees of motor structure; it is continuous caudally with the motor cells of the brainstem, and laterally with the cells of the globus pallidus.

7. The nucleus intercalatus corporis mammillaris is the only group of the corpus mammillare whose cells have the motor type of structure.

8. The structure of the cells of the globus pallidus of the lenticular nucleus is of the motor type, and differs markedly from that of the cells of the putamen. The globus pallidus is accordingly to be considered as the motor portion of the lenticular nucleus.

9. The cells of the substantia nigra are probably not motor.

10. The cell group known as pars reticularis substantiae nigrae is composed of small cells which have a definite motor structure. These cells are unpigmented even in man. To distinguish this motor group sharply from the substantia nigra I suggest the name nucleus intrapeduncularis.

11. The importance of an accurate knowledge of the structure of the cells composing the different cell groups of the central nervous system has not been sufficiently recognized.

12. The experimental worker should determine the structure of the cells from which a tract arises, and of the cells around which a tract ends; the location and extent of such a center can in this manner be accurately determined, and the center may be identified (without the aid of experiment) in other individuals of the same species and homologous centers recognized in different animal forms.

13. A definite type of cell structure corresponds to a definite cell function. When we have studied the cell structure of different cell groups and have correlated definite types of cell structure with definite cell functions we can expect to be able eventually to determine the function of cells which are inaccessible to experiment; this is already possible in the case of the members of the somatic motor chain.

14. The cell structure of a given cell group is distinctive in proportion to the time (both phylogenetically and ontogenetically) during which this cell group has been associated with a definite function. As a consequence of long continued functional specialization of the different cell groups in the mammalian brain it is here that various functional groups are most readily distinguished by means of corresponding differences in cell structure, and these differences are greatest in the adult human brain.

15. The conclusions in this article are based upon a study of serial sections of the central nervous system of the cat, lemur, monkey, and man; all the material was fixed in 95 per cent alcohol, embedded in paraffin, and the sections stained with toluidinblue. Not only has this method proved sufficient for the recognition of motor cells, but it reveals characteristic types of structure in the cells of other groups.

16. The problem of correlation of cell structure with cell function demands a careful and critical study of practically the entire central nervous system; consequently such methods as do not permit of serial sections are of limited value, and the demands as to material and study are so great that the investigator should rely for the most part upon one histological method which sharply reveals the cell structure and with which he is thoroughly familiar.

BIBLIOGRAPHY

Friedemann, M. 1911 Die Cytoarchitektonik der Cercopitheken, etc. Jour. f. Psychol. u. Neurol., Bd. 18, Ergänzungsheft 2.

Jacobsohn, L. 1909 Über die Kerne des menschlichen Hirnstamms, Aus dem Anhang zu den Abhandlungen der königl. preuss. Akad. d. Wiss.

1910 Structur und Function der Nervenzellen. Neurolog. Centralb. No. 20.

Malone, E. 1910 Über die Kerne des menschlichen Diencephalon. Aus dem Anhang zu den Abhandlungen der königl. preuss. Akad. d. Wiss.

1912 Observations concerning the comparative anatomy of the diencephalon. Anat. Rec., vol. 6, no. 7.

Molhant, M. 1910 Le nerf vague (primière partie). Le névraxe, vol. 11.

von Monakow, C. 1909–10 Der rote Kern, die Haube und die Regio subthalamica, etc. Arbeiten aus dem Hirnanatomischen Institut zu Zürich, Hefte 3–4.

Sano, T. 1910 Beiträge zur vergleichenden Anatomie der Substantia nigra, etc. Monatsschrift f. Psychiat. u. Neurol. Bd. 27–28.

THE STRUCTURE OF A TESTIS FROM A CASE OF HUMAN HERMAPHRODITISM

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FIVE FIGURES

The testis which I am about to describe was obtained through the kindness of Dr. E. M. Prince, of Birmingham, Alabama. A report of the case was recently made by Dr. Prince,[1] from which I extract the following history:

> The patient, apparently a girl, eighteen years of age, consulted Dr. Prince stating that she had never menstruated, and that she suffered from headaches supposed to be due to that fact; she had withdrawn from the college she had been attending because of the headaches, which were worse about every twenty-eight days. She appeared to be a healthy, robust girl, refined and intelligent. There was a heavy growth of hair upon the head; the voice was soft and feminine, and the breasts well developed, rather larger than ordinarily seen in a girl of her age. The hips were typically feminine; the mons veneris was rather scantily covered with hair, the labia majora were normal; the clitoris was not enlarged; and the hymen was unruptured. No uterus could be made out by rectal examination. The vagina was about 2 inches long, and terminated in a blind pouch. In the upper part of each labium majus a body could be felt which was freely movable. The diagnosis made was congenital absence of the uterus with hernia of both ovaries. At the operation (exploratory laparotomy) a small body the size of a pecan was found at the usual site of the uterus; and to the left of this there was found an apparently normal ovary with a rudimentary tube. At a subsequent operation the two bodies in the labia majora were removed, and were found to be testes, a diagnosis which was afterwards confirmed by a pathologist.

In a letter Dr. Prince informs me that his patient made an uneventful recovery from the operations; furthermore, that she has the normal liking of a young woman for the society of young men, and is even contemplating matrimony. So that, if the surgeon's diagnosis of an ovary in the pelvis can be accepted, this was a case of true anatomical hermaphroditism; and moreover, in spite of the presence of two extra-abdominal testes, the secondary sex characters of the individual were clearly those of the female.

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[1] E. M. Prince, A case of true hermaphroditism. Jour. Amer. Med. Ass., vol. 58, no. 17, 1912.

In response to my request for some material from this interesting case, Dr. Prince very courteously sent me one of the testes; the other one had been misplaced and could not be found. The gland was received fixed in formalin, and appeared quite normal. The location of the digital fossa of the epididymis showed that it was from the right side of the body. It measured 4.5 x 2 x 1.5 cm., and was acordingly somewhat smaller than the average adult testis. On microscopic examination of sections of the testis (fig. 1) it is seen that the seminiferous tubules are abnormally small. The diameters of a large number measured varied from 0.08 to 0.12 mm., and none were found whose diameter was as great as 0.15 mm. The walls of the tubules are considerably thickened, the thickening being due to hyaline material devoid of nuclei and situated between the tubule-wall proper and the epithelial cells. The lumina of the tubules are filled with cells, the vast majority of which are unquestionably Sertoli cells. Their granular processes freely anastomose with one another forming a syncytium which fills the tubule. Here and there, however, cells may be seen which have some features suggestive of spermatocytes. They consist of a nucleus surrounded by a scanty amount of cytoplasm, the whole lying within a clear area between two Sertoli cells; two such cells are shown in the central tubule in figure 1. The fact, however, that their nuclei are quite small, contain very little chromatin, and, indeed, do not differ from the nuclei of undoubted Sertoli cells, makes it impossible to feel certain as to their nature. Extensive search revealed a very few cells which seemed clearly to be spermatocytes (fig. 2). Such cells have large nuclei fairly rich in chromatin, and occupy clear areas between the Sertoli cells. No spermatids and no spermatozoa could be found, nor were any mitotic figures observed anywhere. Accordingly it is certain that the testis was not functionating so far as the formation of germs cells is concerned.

The interstitial cells are much more numerous than in the normal testis (fig. 1) and appear quite normal. They contain granules which in paraffin sections stain readily with iron-haematoxylin; in frozen sections these granules have a greenish brown tinge, and stain with Sudan III. The connective tissue fibers among the cells do not appear unduly numerous. Thus the structure of this testis is the same as that found in many ectopic testes—a structure which is not only compatible with, but which, according to one hypothesis, is accountable for, the male secondary sex characters of cryptorchids. The body and tail of the epididymis are small, but the head is somewhat enlarged owing to the presence of a firm nodule imbedded in its lateral surface, the structure of which will be described later. In sections of the body of the epididymis the cross sections of the ductus are abnormally small, and the connective tissue between them is thickened. The epithelial cells of the ductus are low and cuboidal, typical columnar cells are entirely absent, and very few cilia can be seen. A ductus deferens could not be located in connection with the epididymis, nor could it be seen in sections through the tail of that structure.

The nodule mentioned above as imbedded in the lateral surface of the head of the epididymis measured 1 x 0.5 x 0.5 cm. On section it was not encapsulated nor separated in any distinct way from the surrounding tissues of the epididymis. Superficially it was continuous with the connective tissue of the tunica vaginalis, while its deep surface passed into the stroma of the caput. Microscopic examination revealed the following structure: Beneath the tunica vaginalis are several layers of rather dense connective tissue and beneath this, masses of cells of epithelioid type arranged in various ways. I have attempted to show the more common modes of arrangement in figures 3, 4 and 5. In the first case (fig. 3) one sees small, more or less oval groups of cells surrounded by thick walls of densely laminated connective tissue; the cell-boundaries are quite indistinct, and the appearance suggests cross-sections of tubules with sclerotic walls. In other instances (fig. 4) the collections of cells are much larger, the cytoplasm stains feebly, while the cell-boundaries are very clearly brought out. Such collections are surrounded by a thin capsule of connective tissue, from which septa pass in to subdivide the collection into smaller groups. Again (fig. 5) the picture presented is that of a section of a ball of cells situated on the end of a stalk of connective tissue, fibers from which surround the mass of cells and also penetrate it. Deeper in beneath the region of the cells the stroma becomes much more cellular, and contains smooth muscle as well as spindle shaped connective tissue cells; its deep surface shades off into the stroma of the caput epididymidis. Everywhere in the nodule there is an astonishing number of blood vessels, whose middle coats especially are much thickened in many instances. It was rather expected that this nodule would prove to be a rudimentary ovary; but I must confess my inability to make the diagnosis and must leave the question of its nature open. Theoretically, it may be a rudimentary sclerotic ovary, a sclerotic adrenal 'rest,' or a vestige of the Wolffian body; and something might be said in favor of each of these views. The fact that it was incorporated in the caput epididymidis and that its connective tissue was directly continuous with that of the epididymis inclines me to regard it as a vestige of the Wolffian body, though, as stated above, I am not able to come to any positive conclusion in the matter.

The prominent features of this case are furnished by the coexistence in the same individual of two ectopic testes with a probable ovary, typical external female genitals, and typical female secondary sex characters. Anatomists are, quite justly, suspicious of cases reported as true hermaphroditism. Doubtless true physiological hermaphroditism in man is unknown. On the other hand, it is certain that male and female sex-glands, one or both being in a more or less rudimentary condition, have been found in the same person; so that in an anatomical sense true hermaphroditism does occur. The exhaustive monograph of v. Neugebauer[2] contains the records of five cases, at least two of which (those of Garre and v. Salén) are undoubtedly examples of this condition. In both of these cases, however, the two glands were combined in one organ constituting a so-called ovo-testis. To these Gudernatsch[3] has recently added a third. The proper classification of the case reported here must remain uncertain so long as it is impossible to make a microscopical examination of the supposed ovary. It is, indeed, improbable that a surgeon of experience in pelvic operations would be mistaken as to a normal ovary; but the mistake has been made a number of times, and the microscopical examination is necessary in every case.

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[2] v. Neugebauer, Hermaphroditismus beim Menschen. Leipzig, 1908.

My primary interest in this case was due to a desire to investigate its bearing upon the theory that attributes the development of male secondary sex characters to an internal secretion of the interstitial cells of the testis. It is obvious that the evidence derived from it is strongly opposed to that theory; for in spite of the existence of an abnormally large amount of interstitial cells, the secondary sex characters were typically female.

The case accentuates the fact that the evidence presented by these abnormal or pathological cases is quite contradictory in its character. Thus, it is by no means rare in pseudohermaphrodites with female sex characters to find ectopic testes which have the same structure as the testes found in ordinary cryptorchids with typical male sex characters. From the study of such cases alone one would very naturally conclude that the interstitial cells are in no way concerned with the development of the secondary sex characters of the male. On the other hand, the theory mentioned above was based by Ancel and Bouin[4] for the most part upon a study of cryptorchid horses and pigs.[5] It seems clear that the question cannot be settled by the study of such evidence. Some method of experimentation must be devised by means of which all the cells of the seminal tubules may be destroyed, leaving the interstitial cells to go on to full development.

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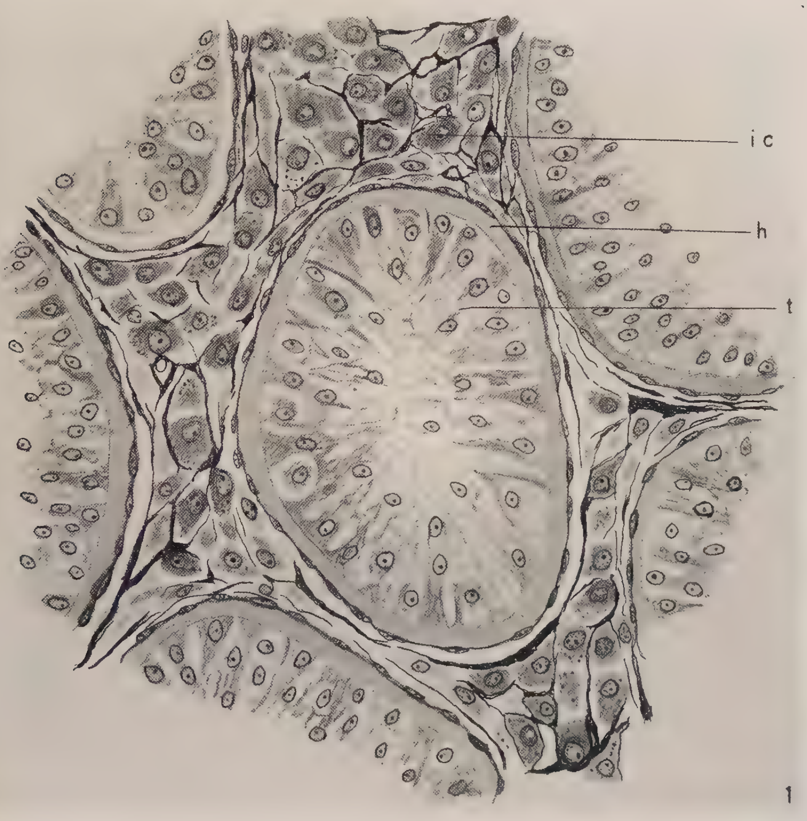
[3] Gudernatsch, Hermaphroditismus verus in man. Amer. Jour. Anat., vol. 11, 1911.

[4] Ancel et Bouin, Recherches sur la rôle de la glande interstitielle du testicule. Jour. Physiolog. et Path., t. 6, 1904.

[5] For a marked example, see a paper by the writer: A peculiar case of cryptorchism. Anat. Rec., vol. 2, 1908.

Fig. 1 *t*, seminiferous tubule; *h*, hyaline portion of tubule wall; *ic*, interstitial cells; iron-haematoxylin stain. × 400.

Fig. 2 *sc*, Sertoli cells; *sp*, spermatocyte; haematoxylin and Congo red stain. × 1000.



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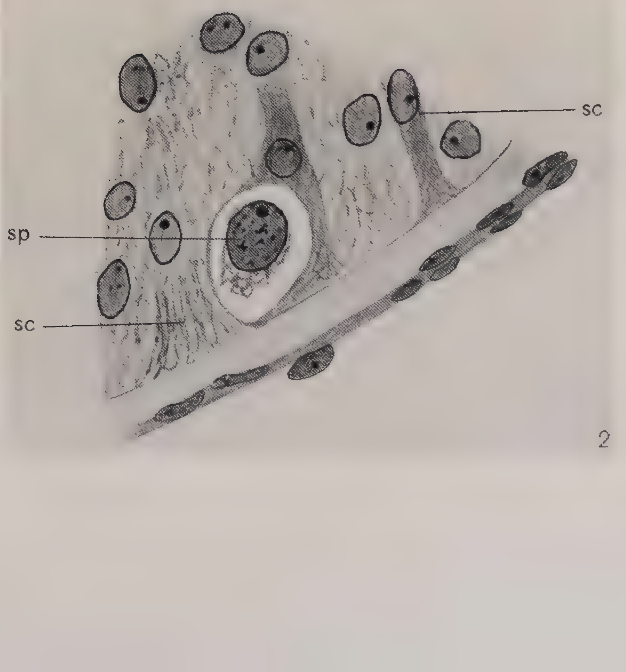

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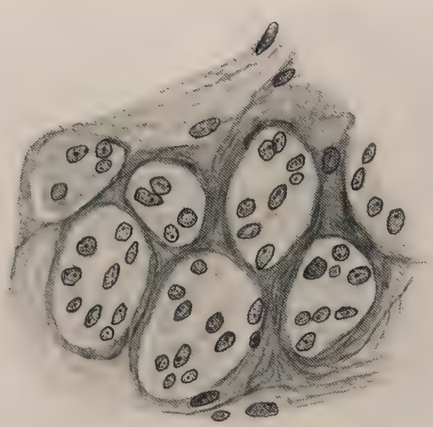

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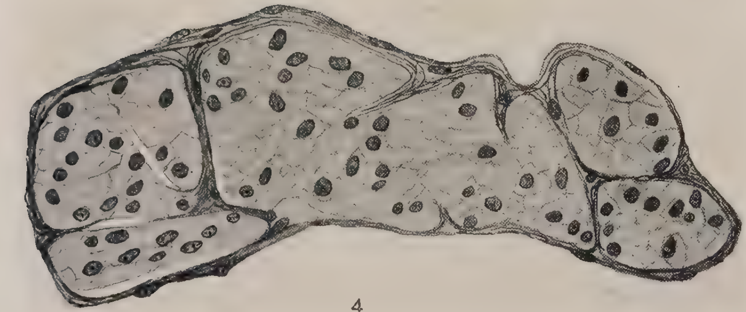

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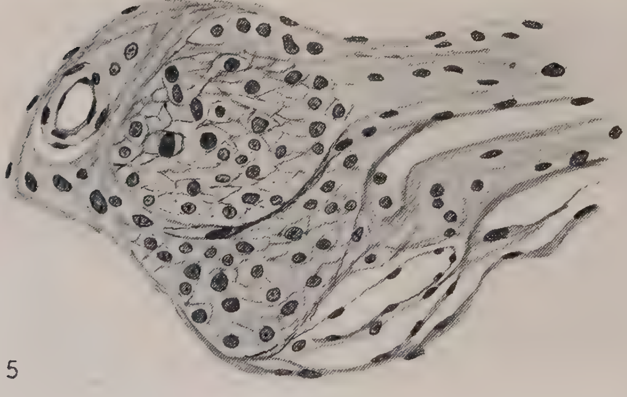

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Figs. 3, 4, 5 Figures to illustrate the modes of arrangement of the cells in the nodule of the caput epididymidis; figure 3, × 500; figures 4 and 5, × 400.

PROCEEDINGS OF THE AMERICAN ASSOCIATION OF ANATOMISTS

TWENTY-NINTH SESSION

In the Anatomical and Histological Laboratories of the Medical Department of Western Reserve University, Cleveland, Ohio, December 31 and January 1, 2, 1912–1913

TUESDAY, DECEMBER 31, 10 A.M. TO 1.00 P.M.

The twenty-ninth session of the American Association of Anatomists was called to order by President Ross G. Harrison, who appointed the following committees:

Committee on nominations: George S. Huntington, *chairman;* Charles R. Stockard, John B. Johnston.

Auditing Committee: Frederick C. Waite, *chairman;* John Warren.

Henry H. Donaldson was appointed a delegate from this associatioh to meet with delegates from the Society of American Naturalists, American Society of Zoologists, and American Physiological Society to consider bringing about a closer affiliation between these societies, coöperation and coördination being desired rather than a fusion.

Address of President Ross G. Harrison, Yale University, "The science of Anatomy, its scope, methods and relation to other biological sciences."

The following papers were presented:

JOHN WARREN, *Harvard University.* The pineal region in mammalia. Lantern.

GEORGE W. CRILE, *Western Reserve University.* Morphologic changes in the brain cells under various conditions. Lantern.

HENRY H. DONALDSON, *The Wistar Institute.* The relative importance of the volume of the neurones versus their number in determining brain weight in the rat and in man.

FREDERIC T. LEWIS, *Harvard University.* The body cavity in human embryos, considered especially in relation to tracheo-oesophageal fistula and the development of the ligaments of the liver. Lantern.

Charles R. Stockard, *Cornell University Medical College, New York City.* The influence of alcohol and ether on the development of mammalian embryos.

Sutherland Simpson, *Cornell University, Ithaca.* The comparative anatomy of the pyramidal tract. Lantern.

George L. Streeter, *University of Michigan.* Corpus striatum and amygdaloid complex in the oppossum. Lantern.

G. Carl Huber, *University of Michigan.* The development of the albino rat from the first cleavage stage to the eighth day. Lantern.

The following papers, announced for this session, were read by title, and by request of the authors transferred to a later session:

Joseph W. Pryor, *State University of Kentucky.* Heredity in normal ossification of bones. Lantern.

Robert R. Bensley, *University of Chicago.* Secretion antecedants in the thyroid gland.

Tuesday, December 31, 2.00 p.m. to 5.00 p.m. Session for the reading of papers, President Ross G. Harrison presiding

S. Walter Ranson, *Northwestern University Medical School.* Fasciculus cerebrospinalis in the white rat. Lantern.

John B. Johnston, *University of Minnesota.* (a The nervus terminalis in mammalian embryos. (b) The morphology of the septal region in the mammalian forebrain. Lantern.

Clarence M. Jackson, *University of Missouri.* Variability of growth in the organs of the albino rat.

S. Hatai, *The Wistar Institute.* Quantitative studies on some of the ductless glands of the Norway rat and its albino variety.

David Marine, *Western Reserve University.* The metamorphosis of the endostyle in Ammocoetes. By invitation. Lantern.

Benjamin F. Kingsbury, *Cornell University, Ithaca.* On the occurrence of a branchial somite (head cavity) in a 3.0 mm. human embryo.

Robert J. Terry, *Washington University.* The occipital region in the mammalian cranium.

John L. Bremer, *Harvard University.* The early branches of the aorta. Lantern. Read by title.

Wednesday, January 1, 9.30 to 11.30 a.m. Session for the reading of papers, President Ross G. Harrison presiding

Charles W. Prentiss, *Northwestern University Medical School.* The development of the membrana tectoria with reference to its structure and attachments. Lantern.

Harold D. Senior, *The University and Bellevue Hospital Medical College.* The eye-muscle nerves of Squalus Acanthias.

Arthur W. Meyer, *Leland Stanford Junior University.* (a) The occurrence and genesis of accessory spleens. (b) The experimental production of hemolymph nodes.

Richard E. Scammon, *University of Minnesota.* (a) The development of the gall bladder in Selachians. (b) On the early development of hepatic trabeculae. Lantern.

J. Parsons Schaeffer, *Yale University.* The occlusion and ultimate obliteration of the ductus arteriosus (Botalli). Lantern.

C. Judson Herrick, *University of Chicago.* The cerebellum of Urodele Amphibia.

Edward F. Malone, *University of Cincinnati.* Histological characteristics common to efferent somatic nerve cells, and the distribution of such cells in certain regions of the mammalian brain.

The following paper, announced for this session, was read by title:

Harvey E. Jordan, *University of Virginia.* The intercalated discs in atrophied heart muscle.

WEDNESDAY, JANUARY 1, 11.30 A.M. BUSINESS MEETING, PRESIDENT ROSS G. HARRISON IN THE CHAIR

Robert R. Bensley was given permission to address the association relative to his relations with the Internationale Monatsschrift für Anatomie und Physiologie. He stated that he had been selected American editor. Manuscripts from American authors were to be addressed to him. He asked for the coöperation and support of his American colleagues.

The Secretary reported that the minutes of the Twenty-Eighth Session were printed in full in The Anatomical Record, volume 6, pages 145 to 152, and asked whether the members present desired to have the minutes as printed read. On motion the minutes of the Twenty-Eighth Session were approved by the association as printed.

John Warren reported for the Auditing Committee as follows: "The undersigned as Auditing Committee have examined the accounts of Dr. G. C. Huber, Treasurer for 1912, and find proper vouchers for all expenditures, and a balance of $318.08" (Signed) Frederick C. Waite, John Warren.

On motion of George S. Huntington the reports of the Treasurer and of the Auditing Committee were accepted and adopted.

The Treasurer made the following report for the year 1912:

Balance on hand December 23, 1911	$263.48	
Total receipts for the year 1912	1440.45	
Total deposits for 1912		$1703.93
Expenditures for 1912:		
Expenses of Secretary-Treasurer, Princeton Meeting	$48.35	
Smoker, Princeton Meeting	7.00	
Postage	40.00	
Printing ($16), Typewriting ($4), and Envelopes, ($5)	25.00	
To 279 subscriptions to volume 13 of American Journal of Anatomy and volume 6 Anatomical Record, @ $4.50	$1255.50	
To 1 subscription to volume 12, and one subscription to volume 14, American Journal of Anatomy, @ $5.00	$10.00	
Total		$1385.85
Balance		$318.08
Balance on hand, deposited in the name of the American Association of Anatomists in the Farmers and Mechanics Bank, Ann Arbor, Michigan, December 26, 1912		$318.08

The Committee on Nominations through its chairman, George S. Huntington, placed before the Association the following names: For members of the Executive Committee for term expiring in 1916, in place of Robert R. Bensley and Robert J. Terry, whose terms of office expired, Arthur W. Meyer, Leland Stanford University, and Charles F. W. McClure, Princeton University.

On motion of Abram T. Kerr, seconded by Thomas G. Lee, the Secretary was instructed to cast a ballot for the election of Arthur W. Meyer and Charles F. W. McClure for members of the Executive Committee for term expiring 1916. Carried.

The Secretary presented the following names, recommended by the Executive Committee, for election to membership in the American Association of Anatomists:

Jacob A. Badertscher, Instructor in Histology and Embryology, *Cornell University, Ithaca, N. Y.*

George W. Bartelmez, Instructor in Anatomy, *University of Chicago.*

Davidson Black, Associate in Histology and Embryology, *Medical Department, Western Reserve University.*

Edward A. Boyden, Teaching Fellow in Histology, *Harvard Medical School.*
H. Hays Bullard, Instructor in Anatomy and Neurology, *University of Pittsburg.*
Edmund V. Cowdry, Associate in Anatomy, *University of Chicago.*
George Morris Curtis, Assistant in Histology, *University of Michigan.*
Thomas J. Heldt, Assistant in Anatomy, *University of Missouri.*
Chester H. Heuser, Austin Teaching Fellow, Histology and Embryology, *Harvard Medical School.*
Helen Dean King, Associate in Anatomy, *The Wistar Institute of Anatomy.*
George B. Jenkins, Assistant in Anatomy, *Johns Hopkins University.*
Frederic P. Lord, Professor of Anatomy, *Dartmouth Medical School.*
Paul Stilwell McKibben, Instructor in Anatomy, *University of Chicago.*
Charles S. Mangum, Professor of Anatomy, *University of North Carolina.*
Max Mayo Miller, Assistant Professor of Anatomy, *University of Louisville.*
Charles W. Prentiss, Associate Professor of Anatomy, *Northwestern University Medical School.*
Edward S. Ruth, Professor of Anatomy, *Wake Forest University.*
Charles H. Swift, Assistant in the Department of Anatomy, *University of Chicago.*
Thomas Wingate Todd, Professor of Anatomy, *Western Reserve Medical School.*
Ivan E. Wallin, Instructor in Anatomy, *University and Bellevue Medical College.*
William A. Willard, Professor of Histology and Embryology, *University of Nebraska.*

On motion, the Secretary was instructed to cast a ballot for election to membership of applicants whose names were read as recommended for election by the Executive Committee. Carried.

The Secretary presented the unanimous recommendation of the Executive Committee for Honorary Membership, the name of Wilhelm Roux, Professor of Anatomy at the University of Halle, author of numerous papers on functional adaptation and developmental mechanics and founder and editor of Archiv für Entwickelungsmechanik.

On motion of George S. Huntington, seconded by Ralph E. Sheldon, Professor Roux was unanimously elected an Honorary Member of the American Association of Anatomists.

On motion of Henry H. Donaldson, seconded by Clarence M. Jackson, the recommendation from the Executive Committee; that the "Order" of the Association setting the limit of time for the reading of a paper at twenty minutes, be changed so as to set the limit of time for the reading of a paper at fifteen minutes, was placed before the Association for consideration.

On motion of John Warren, seconded by George H. Huntington, this recommendation from the Executive Committee was adopted.

Henry H. Donaldson reported that the delegates from the societies desiring a closer affiliation had met and had recognized the desirability of forming a federation, with a joint committee charged with making arrangements for the annual meetings. It was further agreed that each society appoint a representative, these together to hold a further meeting for the purpose of arranging for a meeting place for the ensuing year.

The Secretary of this Association, G. Carl Huber, was appointed, on motion of Thomas G. Lee, seconded by Henry McE. Knower, to represent this association at this second conference, he to be empowered to make what arrangements were deemed necessary.

On motion the business meeting of the Association was adjourned.

On motion the following paper, read by title at the Tuesday morning session, was presented.

Joseph W. Pryor, *State University of Kentucky.* Heredity in normal ossification of bones. Lantern.

Wednesday, January 1, 2. p.m. to 6.00 p.m. Demonstrations Presented

The following demonstrations were presented:

Bennet M. Allen, *University of Wisconsin.* Embryological preparations.

H. Hays Bullard, *Department of Anatomy, University of Pittsburg.* The interstitial granules and fat droplets in striated muscle.

Frederic W. Carpenter, *University of Illinois.* Nerve endings in cranial autonomic ganglia.

Edmund V. Cowdry, *Department of Anatomy, University of Chicago.* Preparations showing mitochondria and neurofibrils.

George Morris Curtis, *University of Michigan.* Photographs of model and drawings of reconstructions of the seminiferous tubule.

Elizabeth H. Dunn, *The Nelson Morris Laboratory for Medical Research, Chicago.* Mitochondria in the cerebral ganglia of the metamorphosing tadpole of Rana pipiens.

J. F. Gubernatsch, *Conell University Medical College, New York City.* Feeding experiments on the tadpole. The action of the glands with an internal secretion.

B. C. H. Harvey and R. R. Bensley, *University of Chicago.* Staining of the secretion in the gastric glands by vital stains, and the use of these as indicators.

S. Hatai, *The Wistar Insitute.* Charts illustrating the growth of viscera in the albino rat.

Chester H. Heuser, *Anatomical Laboratory, Harvard University Medical School.* Charts and stereoptic photographs showing development of the cerebral ventricles.

John B. Johnston, *University of Minnesota.* Models showing: (a) The nervus terminalis in mammalian embryos. (b) The morphology of the septal region in the mammalian forebrain.

Benjamin F. Kingsbury for J. A. Badertscher, *Cornell University, Ithaca.* A series of five models to illustrate the development of the thymus superficialis of the pig, in its relation to surrounding structures.

Frederic P. Lord, *Dartmouth Medical School.* Model showing action of temporo-mandibular articulation.

Rollo E. McCotter, *University of Michigan.* The vomero-nasal nerves in the opossum and other mammals.

Paul S. McKibben, *Anatomical Laboratory, University of Chicago.* Preparations showing mast cells of the meninges of Necturus.

Edward F. Malone, *University of Cincinnati.* Demonstration of toluidin blue preparations of the brain of man and the higher mammals.

David Marine, *Western Reserve University.* Preparations showing the metamorphosis of the endostyle of Ammocoetes.

Charles W. Prentiss, *Northwestern University Medical School.* Laboratory dissections of pig embryos.

S. Walter Ranson, *Northwestern University Medical School.* Preparations of the regenerating sciatic nerve of the dog.

Harold D. Senior, *The University and Bellevue Hospital Medical College.* Staining dishes for serial parafine sections.

George L. Streeter, *University of Michigan.* (a) Models of the corpus striatum and the amygdaloid complex in the opossum. (b) Models showing the development of the membranous labyrinth in the human embryo. The reproductions are made by the Hammer Atelier f. wissenschaftliche Plastik. Munich.

Sutherland Simpson, *Cornell University, Ithaca.* The cortico-spinal fiber system in the raccoon, porcupine, prairie-dog and chipmunk.

Ivan E. Wallin, *Department of Anatomy, The University and Bellevue Hospital Medical College.* (a) Reconstruction of a 2.3 mm. human embryo. (b) The reproduction of wax models by electrolysis.

John Warren, *Harvard University.* Models showing the pineal region in mammalia.

THURSDAY, JANUARY 2, 9.00 A.M. TO 1.00 P.M. SESSION FOR THE READING OF PAPERS, PRESIDENT ROSS G. HARRISON PRESIDING

The following papers were presented:

Charles W. Greene, *University of Missouri.* An undescribed longitudinal differentiation of the great lateral muscle of the king salmon.

Frederick W. Carpenter, *University of Illinois.* Observations on the cranial autonomic ganglia.

Thomas W. Todd, *Department of Anatomy, Western Reserve University.* The clinical significance of lesions of the sympathetic nerves as illustrated by the cervical ribs.

Davidson Black, *Department of Histology and Embryology, Western Reserve University.* The central nervous system in the case of cyclopia in Homo.

E. V. Cowdry, *Anatomical Laboratory, University of Chicago.* The relation of mitochondria to the histogenesis of neurofibrils.

Chester H. Heuser, *Anatomical Laboratory, Harvard University Medical School.* The development of the cerebral ventricles of the pig.

George M. Curtis, *Laboratory of Histology and Embryology, University of Michigan.* Reconstruction of a seminiferous tubule of the albino mouse. Lantern.

Paul S. McKibben, *Anatomical Laboratory, University of Chicago.* The mast cells of the meninges of Necturus.

George W. Bartelmez, *Department of Anatomy, University of Chicago.* The cytoplasmic changes in the pigeon's egg during maturation and fertilization. Lantern.

Elizabeth H. Dunn, *The Nelson Morris Laboratory for Medical Research, Chicago.* Transplantation of the cerebral cortex in the albina rat.

George E. Coghill, *Denison University.* Correlated anatomical and physiological studies of the nervous system of Amblystoma in its embryonic development, with special reference to the nature of the primary ventral root fibers.

Montrose T. Burrows, *Cornell University Medical College, New York City.* The association of a nuclear substance with the formation of amoeboid processes during the division of the heart muscle cell in vitro. Presented by Charles R. Stockard.

William A. Willard, *Department of Histology and Embryology,* University of Nebraska. Cranial nerves of Anolis Carolinensis.

Frederic T. Lord, *Department of Anatomy, Dartmouth Medical School.* Observations on the temporo-mandibular articulation.

The following papers announced for this session were read by title:

William H. F. Addison and H. W. How, *University of Pennsylvania,* The contents of the foetal mammalian lung. Lantern.

Robert Bennett Bean, *Tulane University.* (a) Three forms of the human nose. (b) The nose of the Jew and the quadratus labii superioris muscle.

John Sundwall, *University of Kansas.* Interstitial cells in the choroid plexus.

On motion the Association tendered its sincere thanks and appreciation to Prof. Frederick C. Waite and to the other members of the staff, as also to the authorities of The Western Reserve University for the very efficient arrangements made and for their hearty coöperation in furthering the success of this meeting.

On motion the American Association of Anatomists closed its twenty-ninth session and adjourned.

G. Carl Huber,
Secretary-Treasurer.

AN UNDESCRIBED LONGITUDINAL DIFFERENTIATION OF THE GREAT LATERAL MUSCLE OF THE KING SALMON

CHARLES W. GREENE

Department of Physiology and Pharmacology, Laboratory of Physiology, University of Missouri

Numerous references in the literature of comparative anatomy give statements describing the segmental arrangement within the great lateral muscles. Also, there are descriptions of the longitudinal cleavage which is accomplished by the development of great longitudinal septa. For example, the dorsal and ventral halves of the lateral muscle are divided in the bony fishes by a median longitudinal septum which extends from the surface of the muscle down to the skeletal axis. In the Selachians additional longitudinal septa of similar type are found.

In my work on the king salmon of the west coast, I have found evidence of a differentiation of the lateral muscle along lines to which thus far no references have been found in the literature. In histological studies of the distribution of fats in the salmon musculature under different physiological conditions, it came out that the superficial portion of the lateral muscle had entirely different histological and apparently also physiological characteristics from those of the deep portion. In other words, there is a longitudinal cleavage of the great lateral muscle in a plane essentially parallel with its surface. In so far as the distribution of fats is concerned, the difference was briefly alluded to in a report before the Physiological Society last year. The histological characteristics of this superficial type of muscle fiber have been published in a brief description in The American Journal of Anatomy for last May.[1]

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[1] Greene, Charles W. A new type of fat storing muscle in the salmon, Oncorhynchus tschawytscha. Am. Jour. Anat., vol. 13, pp. 179–182, 1912.

This differentiation is especially characterized by the differences in the histological structure of the muscle fibers. The fibers of the superficial muscle are relatively smaller in diameter than those of the deep, and are more uniform both in diameter and in relation to their placement with each other. They also differ in the fibrillar structure, the fibers of the superficial muscle having a relatively greater amount of sarcoplasm than the fibers of the deep muscle.

The greatest and most striking differentiation noticed was in the behavior of the muscle toward fat. The superficial muscle in all stages of nutrition carries a relatively heavy load of fat disposed *within* the muscle fibers. In the prime conditioned king salmon this load of fat amounts to the enormous proportion of 30 per cent and more of the wet weight of the tissue.

In gross anatomical features the superficial portion of the great lateral muscle is differentiated by a markedly darker color, by a more compact consistency as a whole, and by the fact that it is definitely separated from the deeper portion by a distinct and continuous septum. The septum is intimately bound both with the superficial and the deep muscle, so that nowhere is there a distinct bursa or other connective tissue disposal whereby the surface of one muscle can slide over the surface of the other. The mass of the superficial muscle is most highly developed in the median line and becomes thinner both in the dorsal and in the ventral directions. It, too, is separated into two parts by the median longitudinal septum which divides the entire lateral muscle mass.

The deep portion of the great lateral muscle of the king salmon is of the rich characteristic pink color which is the most obvious diagnostic feature in contrast with the superficial portion. However, more fundamental characters are present. Of these the most striking is found in the size and interrelations of the deep muscle fibers. These fibers vary in cross sectional diameter from 25 to 250 μ and even more. The fibers are not perfect cylinders but of a form which gives the impression that they are more or less compressed. Cross sections rarely present circular outlines, the rule in the superficial, but instead show great variety of polygonal outlines. In the fattest fishes the deep muscle has its fat chiefly disposed *between* the fibers whereas in the superficial muscle the fat is chiefly *within* the fibers.

In the grosser anatomical features the deep muscle bears the relations usually described for the lateral muscle as a whole. Fuller details of comparison are in process of publication in the Bulletin of the United States Bureau of Fisheries.

Whether or not a given mass of muscle fibers is to be considered as separated into distinct muscles, or only as differentiated into imperfect divisions of the larger mass depends upon a number of factors, and one's decision must be arrived at by a consideration of the sum total of these factors. The superficial portion of the great lateral muscle mass in the king salmon is not set off from the deep portion in such a way that its contractions will produce any peculiar and characteristic motion different from that which the deep portion of the mass can produce. Experiments have not in any way shown that the superficial portion is characterized by the ability to contract independent of the remainder of the mass. It is, however, bounded by a definite separating layer of connective tissue and can readily be peeled off from the deeper portion by maceration. Sections show that the segmental septa of the superficial muscle are not coincident and definitely continuous with the septa of the deep portion.

After all, the most diagnostic features of the superficial muscle are (1) the microscopic revelation as to the uniformity and small size, as well as structural peculiarities of fibers, (2) its different behavior toward fats, (3) its characteristic darker color, and (4) its separation from the deep portion by a definite bounding septum. On the whole these features seem to be quite sufficient to justify the recognition of a differentiation of the lateral musculature into two distinct muscles. For these the names 'musculus lateralis superficialis,' and 'musculus lateralis profundus,' respectively, are suggested.

BOOK REVIEW

THE DEVELOPMENT OF THE HUMAN BODY: A MANUAL OF HUMAN EMBRYOLOGY. By J. Playfair McMurrich. Philadelphia, P. Blakiston's Son and Company, fourth edition, 1913, pp. 8 + 495, 285 figures, $2.50 net.

A new edition of McMurrich's Embryology has just appeared. The general character of the previous editions is retained, particular attention being given to the development of organs and less space devoted to the early stages of the embryo. Parts of the book have been re-written and other parts revised. The numerous typographical errors so conspicuous in the third edition have been eliminated.

The volume is of pocket size with flexible binding. The large, clear type has been retained. Perhaps the most important feature of the book is the author's clearness of expression. If embryology is to be an aid to anatomy it would appear desirable to find some royal road to this science, which is at present perhaps more difficult than adult anatomy. The student is usually bewildered by serial sections unless guided by a very clear presentation of the subject. McMurrich has achieved this end at the expense of many details, and no doubt rightly. Yet, the large mass of facts contained in this small book seems remarkable.

A few passages are ambiguous if not erroneous, and may deserve mention. McMurrich describes the observations of Will on gastrulation in the Gecko, but transposes Will's terminology of primary and secondary endoderm. If gastrulation in vertebrates means anything, certainly the formation of endoderm by invagination is the primitive process and is 'primary' from the standpoint of phylogeny, whereas delamination is a secondary method of formation although it does occur earliest in the development of mammalian embryo.

On page 60 the author describes the origin of the mesoderm as follows: "the layer of enveloping cells splits into two concentric layers, the inner of which seems to be mesodermal in its nature and forms a layer lining the trophoblast," and again on page 110: "the extra-embryonic mesoderm, instead of growing out from the embryo to enclose the yolk sac, splits off directly from the enveloping layer." And on page 55: "a splitting of the enveloping layer has occurred, so that the wall of the ovum is now formed of three layers, an outer one which may be termed the trophoblast, a middle one which probably is transformed into the extra-embryonic mesoderm of later stages, though its significance is obscure, and an inner one which is the primary endoderm." I know of no primate, however, in which it has been demonstrated that any part of the mesoderm is delaminated from the trophoblast. McMurrich supposes a separate origin of the extra-embryonic mesoderm. He may be correct, since the origin of the mesoderm is unknown in man.

The relation of blood vessels to endoderm in the liver anlage is described on page 308 as follows: "Shortly after the hepatic portion has been differentiated, its substance becomes permeated by numerous blood vessels (sinusoids) and so divided into anastomosing trabeculae." Since these blood vessels arise by a breaking up of the vitelline veins, which are present before the liver anlage appears, it might seem more logical to say that the liver invades the vitelline veins than that the veins invade the liver.

McMurrich describes the separation of the coelomic cavities as they occur in the rabbit. The separation of the pericardium from the other cavities is simpler in man in that there are no openings ventral to the viteline veins that have to be closed. This is described in Keibel and Mall's Handbook (vol. 1, p. 526) as follows: "In the rabbit the pericardial coelom ends in two dorsal and two ventral recesses, all four of which connect subsequently with the peritoneal coelom. However, only the dorsal recesses break into the peritoneal coelom in the human embryo." A description of the simpler condition in the human embryo might be preferable in a textbook.

Finally, there is a point which is of no evident importance in embryology, but since McMurrich has brought it up, we will consider it very briefly. He describes protoplasm as having a visible reticular or possibly alveolar structure. This reticular 'theory' is based on fixed material, although is it well known that fixing fluids produce the same appearance in clear gelatine jelly or clear albuminous fluids. Formalin and osmium tetroxide do not produce a reticular structure in gelatine jelly and protoplasm fixed with them appears homogeneous. Bütschli observed an alveolar structure in 'living' protoplasm under certain conditions, but this appearance seems to be exceptional or possibly abnormal. With the ultra-microscope of Siedentopf and Zigsmondy, particles smaller than the largest molecules may be made very evident. With this instrument the protoplasm of erythrocytes, and both nucleus and cytoplasm of frog erythrocytes, appear absolutely homogeneous, until injured by abnormal conditions. When transferred from the normal medium to even so good an imitation as Ringer's solution coagulations begin to appear. The numerous deutoplasmic granules in many cells prevent a universal application of this method.

To sum up: McMurrich's Embryology may be considered as a very convenient and desirable text book for medical students. It might also be used as a brief reference book provided the subject matter be verified by looking up the literature cited at the end of each chapter.

J. F. McClendon.

AN ATLAS OF THE DIFFERENTIAL DIAGNOSIS OF THE DISEASES OF THE NERVOUS SYSTEM. ANALYTICAL AND SEMEIOLOGICAL NEUROLOGICAL CHARTS. By Henry Hun, M.D., Professor of Diseases of the Nervous System in the Albany Medical College. The Southworth Company, publishers, Troy, New York, 1913.

A very interesting arrangement of the diagnostic apparatus of one of the most fruitful workers and teachers in neurology, in the form of tables, this book presents a huge mass of data in a very firm system of nominally 22 logically arranged charts, presented on 243 pages, some of which are double or triple, embodying 1405 distinct items or topics; with 14 figures (of motor points, curves, etc.) interspersed in the tables. This is followed by 18 schematic drawings and figures of the brain surface, the cranial nerve nuclei, the cord, the types of degeneration in the cord, the bladder control and the segmentation. Twenty-eight pages are devoted to the index referring to charts and items (not to pages). Most of the charts show a remarkable ingenuity of arrangement of the mass of facts, and a surprising economy of repetition and diction, but for this very reason they do not lend themselves to continuous reading, and probably work best as a system of notes of a systematic course given by a teacher who has to add the spirit and matrix of the connections, or then as a reference book. The extensive use of a perpendicular arrangement of words and the many subdivisions require a certain amount of special habituation. The criticism of detail would seem captious. The book is probably more adapted to the use of teachers of classes in nervous diseases than to the mere student unless the latter is trained to use systematically the general method of procedure. A booklet with casuistic material showing the use of the atlas would form a very desirable introduction and probably a condition for the wider usefulness of this work among students.

A. M.

THE HISTOLOGY OF THE ENTERON OF THE FLORIDA ALLIGATOR

A. M. REESE
West Virginia University, Morgantown

NINETEEN FIGURES

INTRODUCTION

It has long been known that the sea lamprey, Petromyzon marinus, during the spawning season, when the body is distended with eggs, takes no food, and that the digestive tract during this period shrivels up until it is reduced to a mere thread. This condition doubtless obtains in other forms as well, though it has not been actually observed by the writer elsewhere.

A number of small alligators that were kept alive in the laboratory during the past year caused the writer to wonder whether any very marked change had taken place in their digestive tracts during the months they took no food.

In captivity, especially if the water in their tank be kept cold, alligators may refuse food for five or six months. Whether, during the winter months, in their native haunts, they entirely cease feeding, the writer has had no opportunity to observe, though it is popularly reported that such is the case.

Mr. H. I. Campbell, proprietor of the Arkansas Alligator Farm, at Hot Springs, Arkansas, writes in answer to a letter of inquiry, as follows:

> Our alligators stop eating the first week in October and do not begin to eat until the latter part of April.
>
> We have experimented with our stock to see if we could get them to eat in the winter, and found that by keeping the water in the tanks at a certain temperature, they would eat, but we found out that the warm water would make their bowels move, and that they would not eat enough to keep themselves up, as in the summer, and as a result they

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would become very poor and thin, so we do not force them to eat any more.

In their wild state they go into their dens under water and remain dormant all winter.

The first alligator from which tissues were taken was about a year-and-a-half old, and measured 18 inches in length. It was killed in March after a fast of several months, probably four or five, possibly more, though it was not in the writer's possession for so long a time.

Although carefully fixed in the usual fluids, the epithelial structures from this animal were not as clearly defined in most cases, as could be desired; this rather unsatisfactory fixation may have been due to some physiological condition characteristic of the period of hibernation. That this was the case seems likely from the better fixation obtained by the same methods in the case of animals killed during the feeding season.

The other animals from which tissues were taken were considerably smaller than the one mentioned above. They were killed early in the fall, after having been fed regularly for about five months upon bits of meat, both raw and cooked.

THE TONGUE

The covering of the tongue was studied in two regions, near the free end, and towards the base.

A section of the former region, drawn under high power, is shown in figure 2. It consists of a dense mass of fibrous tissue, *a*, and small scattered cells, overlaid by a stratified epithelium of eight or ten layers. Only a small part of the fibrous base, just beneath the epithelium, is here shown. It is a dense areolar tissue with the elastic fibers apparently predominating.

The epithelium, *e*, consists, as has just been said, of about eight or ten layers of cells, those at the base being generally cuboidal in shape, while towards the surface the cells become more and more flattened until at the surface they form a thick horny layer, *h*, in which no nuclei can be seen. The cells of the horny layer are flattened into mere fibers, which, at places, are seen projecting from the surface. The boundary between the horny cells

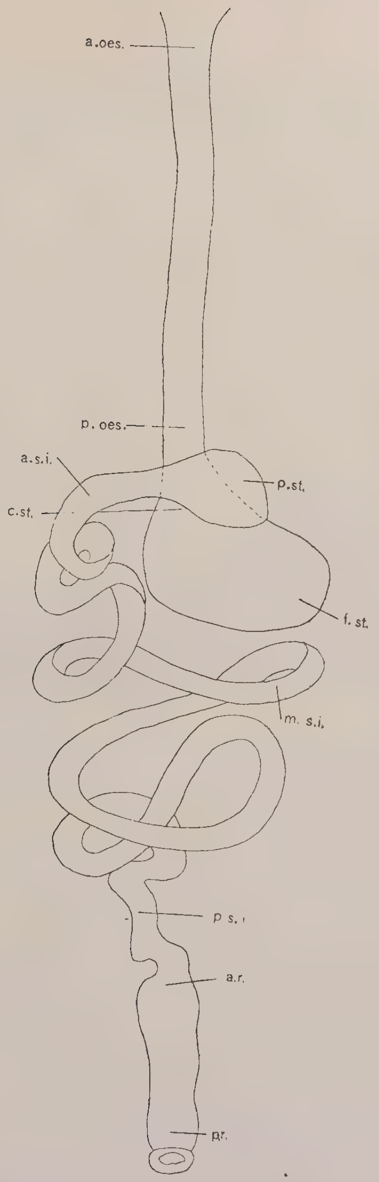
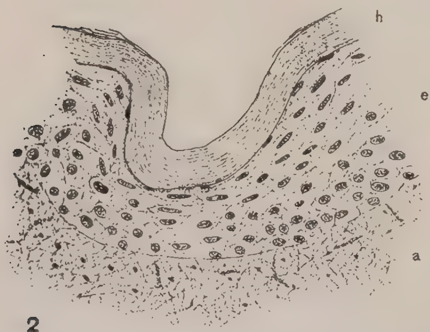


Fig. 1 An outline of the digestive tract of the alligator from the beginning of the oesophagus to the cloaca, to show the planes of the sections that were studied. *a.oes.*, anterior oesophagus; *a.r.*, anterior rectum; *a.s.i.*, anterior small intestine; *c.st.*, cardiac stomach; *f.st.*, fundic stomach; *m.s.i.*, middle small intestine; *p.oes.*, posterior oesophagus; *p.r.*, posterior rectum; *p.s.i.*, posterior small intestine; *p.st.*, pyloric stomach.

and those beneath is quite distinct, though perhaps not quite so sharp as shown in the figure under discussion.

In a previous paper, the writer ('10) noted that the dorsum of the tongue is covered with small, evenly distributed papillae, easily seen by aid of a hand lens. These so-called papillae are here seen to be hardly papillae at all, but small folds or wrinkles, although the epithelium is somewhat thickened at intervals. No glands are to be seen in this region of the tongue.



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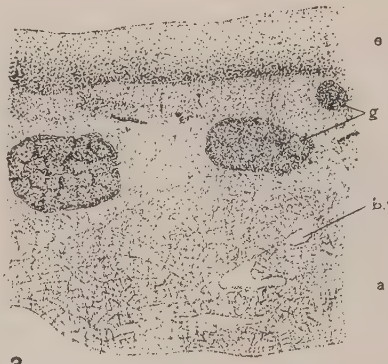

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Fig. 2 The covering of the anterior region of the tongue of the hibernating animal, under fairly high magnification; the plane of this section is not shown in figure 1, *a*, areolar tissue; *e*, epithelium; *h*, horny layer of epithelium.

Fig. 3 Covering of the posterior region of the tongue of the hibernating animal, showing glands, under low magnification; *a*, areolar tissue; *bv*, blood vessels; *g*, glands; *e*, epithelium.

The only difference between the anterior region of the tongue during hibernation and during the feeding season seems to be in the scaly layer of the epithelium. Instead of the compact, sharply differentiated layer of scaly cells seen in figure 2, the anterior region of the tongue during feeding is covered with a layer of rather loose, scaly cells, in most of which the nuclei may be seen. No difference in the amount of sloughing off can be noticed as is the case with the epithelium of the roof of the mouth.

Figure 3 represents a section, under very low magnification, of the covering of the base of the tongue. The areolar tissue, *a*, is about the same as in the preceding section, except that it is more compact just under the epithelium than it is in its deeper regions. It seems also more vascular than in the preceding section.

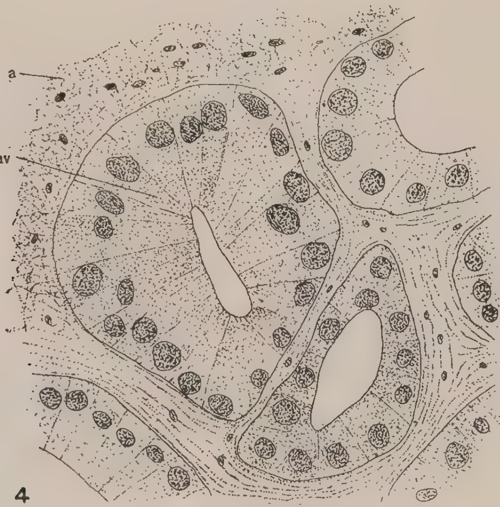
The epithelium, *e*, is of the stratified squamous variety, but consists of many more layers of cells than in the preceding section, and is hence several times as thick. While its cells are flattened towards the surface, after the manner of this kind of epithelium, they do not form the definite horny layer described above.

The most marked difference between the two regions of the tongue is the presence, in the posterior or basal region, of numerous glands, *g*, probably mucous- or slime-secreting. They are thickly scattered through the areolar base, close beneath the epithelium. Two large and one small gland are shown in the figure under discussion. Each gland opens to the surface by an apparently wide duct, but since no good section of such a duct was obtained it is not shown in the figure. Although the rest of the tissue was well preserved and showed cell structure clearly, it was with difficulty that the details of the glands could be determined.

A high power drawing of a portion of one of the glands is shown in figure 4. The large alveolus, *av*, to the left, is from the peripheral region of the gland and is surrounded, on its free side, by the areolar tissue described above. The inter-alveolar spaces, which are somewhat exaggerated in the figure, are filled with fibers which are arranged more or less in layers and hence appears different from the surrounding areolar tissue. The alveoli are circular or elongated in section, and have fairly wide lumina. They are lined with a single layer of columnar or cuboidal cells which are very granular, so that their walls are difficult to determine. Each cell contains, near its base, a very large, usually spherical nucleus. These nuclei stain darkly and give the dark appearance to the glands as seen under low magnification, especially in rather thick sections.

During feeding the epithelium of this region of the tongue consists of fewer layers of cells than during hibernation but is otherwise unchanged from what is described above. The glands consist, at least in all of the material examined, of much fewer alveoli than are shown in figure 3. One of these glands is shown in figure 5.

Although no more care was used in fixation than in the corresponding tissue of the hibernating animal the glands here show



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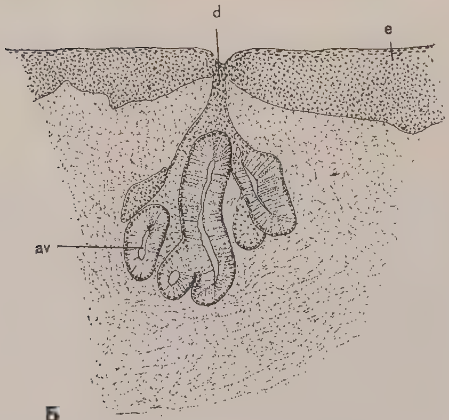

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Fig. 4 One of the glands from the posterior region of the tongue of the hibernating animal, under high magnification; *a*, areolar tissue; *av*, alveolus.

Fig. 5 One of the glands from the posterior region of the tongue of the feeding animal, under somewhat higher magnification than used in figure 3; *av*, alveolus; *d*, duct of gland; *e*, stratified epithelium.

their cell details far more clearly than in the former tissue; this may have been partly due to the latter sections being thinner.

The glands are of a compound, tubulo-alveolar type; although numerous sections through ducts were obtained (as in fig. 5), no details of these ducts could be seen.

As noted above, and as may be seen by comparing figures 3 and 5, the gland during hibernation, at least in the animals studied, consists of many more alveoli than during the feeding season; this, of course, might not prove to be always the case if larger numbers of animals were studied; the difference in the ages of the animals might have caused this difference in the glands. In the material studied the largest glands from the hibernating animals consist of more than twice as many alveoli as the glands in the feeding animals. As seen under high magnification there is no noticeable difference in the glands at the two seasons.

THE ROOF OF THE MOUTH

In the paper mentioned above the author ('10) notes that the papillae on the roof of the mouth are evenly distributed and are more distinct than those of the dorsum of the tongue. One of these papillae as seen under fairly high magnification is shown in figure 6.

The areolar tissue, *a*, forming the base of the section is of about the same character as seen in the section of the tongue. Less than one-tenth of the thickness of the entire areolar base is shown in this section.

The epithelium, *e*, where not thrown into papillae, has also about the same character as that of the anterior region of the tongue—the same number of cell layers and the same distinct horny layer.

At intervals the thickness of the cellular part of the epithelium is greatly increased, and at the same time the horny layer is also thickened, to form distinct papillae like the one shown in the figure. These, as has been said, are comparatively small and have the shape of a blunt cone. The center of the cone is, of course, made up of the cellular epithelium, while the outside is overed with the thickened horny layer from which fibers, *f*, are often seen projecting. Near the apex of the cone the nuclei are larger and more widely scattered than those at the base.

No glands were seen in the roof of the mouth of the hibernating animal, but since the entire roof was not sectioned it is probable that they may exist in some regions; in fact, as noted below, sections through the posterior region of the roof of the mouth of the feeding animal do show numerous glands.

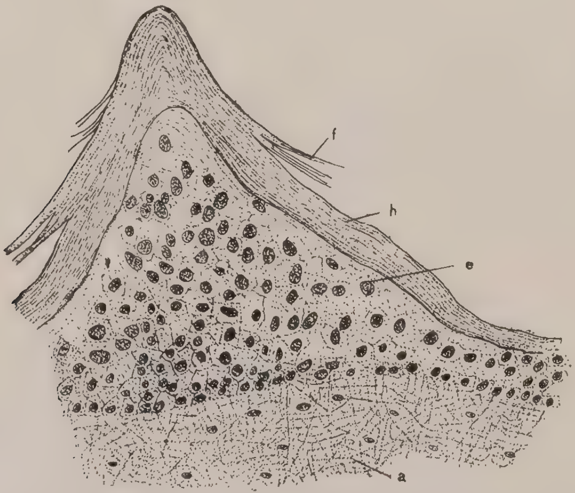


Fig. 6 The covering of the roof of the mouth of the hibernating animal, under fairly high magnification; *a*, areolar tissue; *e*, epithelium; *h*, horny layer; *f*, fibers of horny layer.

As might be expected there is comparatively little difference between this region of the enteron during hibernation and during the feeding season. The only noticeable difference is in the stratified epithelium; that of the feeding animal not only has less sharp papillae but has also a much thinner scaly layer of cells. As is seen in the figure of the roof of the mouth during hibernation the scaly cells make up, except on the papillae, nearly or quite half of the thickness of the epithelium, while in the feeding animal they make up not more than one-fourth or one-third of the entire epithelium. Very few cells are seen sloughing off as in figure 6; possibly the act of feeding keeps the superficial scaly cells rubbed off smooth.

In the extreme posterior region of the roof of the mouth the epithelium consists of a greater number of layers (though the number is very variable) than in the region shown in figure 6. In this posterior region, as noted above, glands are found. These glands have the same structure as those described in connection with the posterior region of the tongue.

THE OESOPHAGUS

Sections of the oesophagus were made from two regions, an anterior, half-inch caudal to the pharynx, and a posterior region, half-inch cephalad to the opening of the oesophagus into the stomach (fig. 1).

The general structure of the wall of the oesophagus, as seen under a low magnification, will first be described, after which the minute structure of the epithelium, as seen under high magnification, will be discussed.

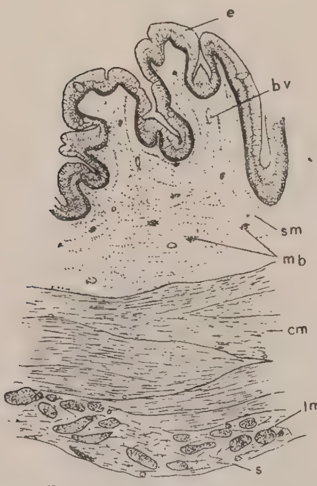
In the *anterior region* the usual layers of the vertebrate enteron are present, except, possibly, the muscularis mucosa.

The epithelium, to be described later, is, together with the submucosa, thrown into complicated folds; its closely arranged and darkly stained nuclei cause it to stand out in strong contrast to the other tissues of the section (fig. 7, *e*).

The submucosa, *sm*, is of considerable thickness. It is composed of a fairly dense mass of connective tissue, mainly elastic fibers, through which are scattered small blood vessels, *bv*, and small dark areas, *mb*, that are apparently longitudinal bundles of involuntary muscle fibers. These few and scattered fibers probably represent the muscularis mucosa that is so well developed in the posterior region of the oesophagus.

Outside of the mucosa is a thick circular layer of involuntary muscle fibers, *cm*, the fibers being collected into irregular bundles, between which are narrow spaces filled with connective tissue that contains a few small blood vessels.

Surrounding the circular layer is a thinner and less clearly defined layer of longitudinal muscle fibers, *lm*. The muscle bundles are more definite than in the circular layer and are separated from each other by a considerable amount of connective tissue with a few small blood vessels.



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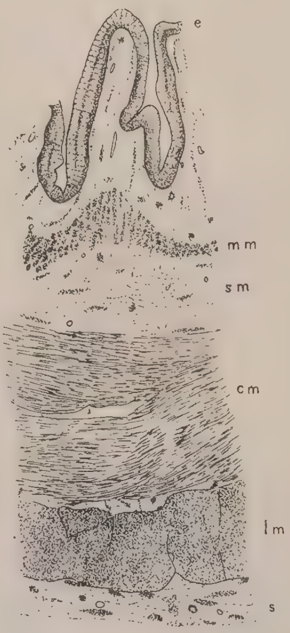

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Fig. 7 A transsection through the anterior region of the oesophagus of the hibernating animal, under low magnification; *bv*, blood vessels; *mb*, muscle bundles; other letters as in figure 8.

Fig. 8 A transsection through the posterior region of the oesophagus of the hibernating animal, under low magnification; *e*, epithelium; *cm*, circular muscles; *lm*, longitudinal muscles; *mm*, muscularis mucosa; *sm*, submucosa; *s*, serosa.

The serosa, *s*, is here quite indistinct. It consists of a slightly vascular connective tissue which cannot be distinctly differentiated from the connective tissue of the longitudinal layer.

In the *posterior region* of the oesophagus, as may be seen by comparison of figures 7 and 8, the wall as a whole is about one-third thicker than in the anterior region just described, though how much of this difference is due to different degrees of distension or contraction it is hard to say.

The epithelium, *e*, is in the tissue studied thrown into less complicated folds than in the anterior region, and is not so thick.

The submucosa, *sm*, if the entire layer may be so called, has about the same thickness and structure as in the more anterior region; but instead of the small and widely scattered bundles of longitudinal muscle fibers there is a distinct layer of muscle which may be called the muscularis mucosa, *mm*, lying about midway between the epithelium and the circular muscle layer.

The muscularis mucosa is somewhat variable in thickness and is thrown into folds that correspond to the larger folds of the epithelium and the submucosa; one of these folds is shown in figure 8. The fibers of the muscularis mucosa are apparently all longitudinal in position.

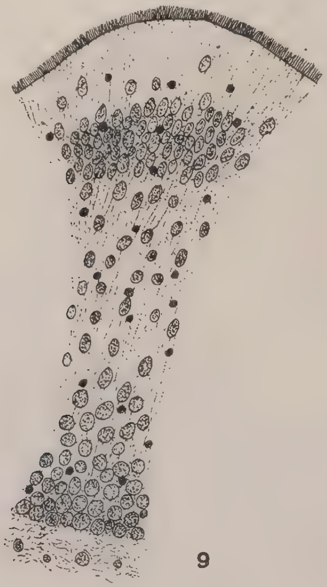
Outside of the submucosa is a layer of circular muscle fibers, *cm*; it is here somewhat wider and more dense than in the anterior region.

The longitudinal muscle layer (fig. 8, *lm*) is much wider and more compact than in the anterior region. The fibers are indistinctly divided into large irregular masses as shown in the figure.

The serosa (fig. 8, *s*) is a varying but fairly thick layer that is quite distinct from the longitudinal muscle layer. It consists of the usual connective tissue groundwork with scattered bloodvessels.

The epithelium, as was said above, is thicker and somewhat more folded in the anterior than in the posterior region, and in the former region is partially ciliated while in the latter cilia are entirely wanting. With these exceptions the epithelium is practically the same in the two regions.

Figure 9 represents the epithelium from the anterior region as seen under high magnification. The outlines of all the cells could not be determined, but if each nucleus represent a cell there are twenty-five or thirty layers of cells. The nuclei are arranged in two dense, irregular groups, one along the base of the epithelium, the other about two-thirds of the distance from the base to the free border. The basal nuclei are perhaps slightly larger and more rounded than those of the distal group. Between these two groups are numerous more scattered nuclei; while scattered through the epithelium, except near the free border, are smaller, round nuclei that stain somewhat darker than the rest; these, from their size and appearance, seem possibly to belong to an invisible network of connective tissue that has penetrated the epithelium from the surrounding mucosa.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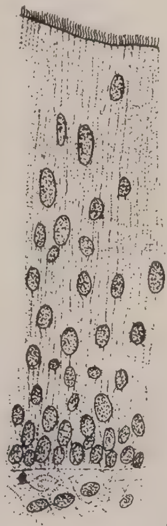
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Fig. 9 The epithelium of the anterior region of the oesophagus of the hibernating animal, under high magnification.

Fig. 10 The epithelium of the anterior region of the oesophagus of the feeding animal, under high magnification.

The free border of the epithelium consists of long, ciliated, columnar cells in which the cell walls may be easily seen. The cilia are of average length and even in this anterior region are not everywhere present; possibly they are arranged in bands, but the material at hand was not sufficient to determine this. As was noted above, cilia are wanting in the posterior region.

The only differences noted in the anterior region of the oesophagus between the feeding and the hibernating conditions, are in the muscularis mucosa and the epithelium. As was noted above, the muscularis mucosa is practically absent in the hibernating stage, being represented only by a few small, scattered bundles of longitudinal muscle fibers; while in the feeding stage there is a narrow but fairly distinct layer to represent the muscularis mucosa.

The difference in the appearance of the epithelium is not striking. The nuclei are somewhat larger in the feeding stage and, instead of being crowded into a basal and a median zone, as noted in the hibernating conditions, they form a dense basal zone, but show no indication of medial zone. From the dense basal zone the nuclei become more scattered towards the free surface and are rarely found closer to the surface than is shown in figure 10. The smaller nuclei scattered among the larger ones, noted in connection with the hibernating stage, are not here seen. As in the hibernating stage cilia are present on some but not all cells of this region.

The only noticeable difference between the feeding and hibernating conditions of the posterior region of the oesophagus, is in the epithelium, which, as in the feeding condition of the anterior oesophagus, exhibits but one zone of closely set nuclei, that at the base of the epithelium.

THE STOMACH

The stomach was sectioned in three regions, as shown in figure 1: (1) in the cardiac region very near the opening of the oesophagus; (2) in the middle or fundic region; and (3) in the region near the opening of the pylorus. The first two sections are in the first or large region of the stomach; the third section is in the second or small region of the stomach (fig. 1).

The wall as a whole is thickest in the fundus, being there practically twice as thick as in the pyloric and half again as thick as in the cardiac region. This great thickening is due mainly to a thickening of the middle or oblique layer of muscle, which is here remarkably developed. The mucosa is of nearly uniform thickness in the different regions and will be described later.

Since there is no striking difference beside that of thickness in the general structure of the wall of the different regions, the pyloric region, as seen under low magnification, will now be described (fig. 11).

The mucosa, *m*, consists of fairly long glands underlaid by a well marked muscularis mucosa, *mm*, the latter exhibiting a compact circular layer over a wider but more scattered layer of longitudinal fibers. A considerable amount of fibrous connective tissue lies among the muscle fibers. The circular layer of the muscularis mucosa sends towards the surface numerous strands or septa between the glands; six or eight of these are seen in the figure. These strands are not nearly so numerous in the large region of the stomach. As was said, the outer or longitudinal layer of the muscularis mucosa is wider but less compact than the circular and its bundles of fibers are seen in the figure as a layer of large, scattered dots just beneath the circular layer.

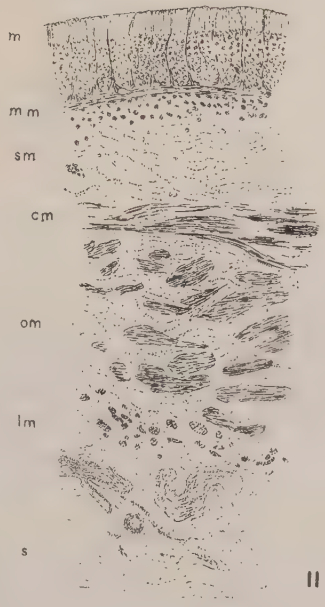
The submucosa, *sm*, is of average thickness and density. In the fundic and cardiac regions it seems to extend between the circular and oblique layers; at any rate, there is a considerable layer of connective tissue between these two muscular layers.

The circular muscular layer, *cm*, is of only moderate thickness and is of rather a loose character. In the pyloric region it is not very distinct from the underlying oblique layer, but in the other regions, as has just been said, it is separated from the oblique layer by a considerable layer of connective tissue like that of the submucosa.

The oblique layer, *om*, even in this section of the pyloric region is the thickest of the three muscle layers; while in the cardiac, and especially in the fundic, regions it is of great thickness, as was noted above, and is made up of larger bundles with less intervening connective tissue.

The outer or longitudinal muscle layer, *lm*, is comparatively little developed and consists of small, rather scattered bundles of muscles with a correspondingly large amount of connective tissue. This connective tissue passes insensibly into that of the surrounding serosa, *s*, a loose, vascular layer of varying thickness and density, shown very thick in figure 11, but often much thinner.

So far as could be determined, the mucous membrane has the same structure in both anterior and middle regions of the stomach. That of the pyloric or small region, although fixed, stained, et cetera, just as carefully as the rest, did not show cell details sufficiently well to draw; the ducts of the glands in this regions are fairly distinct but the deeper parts of the glands have the appearance of series of alveoli or large adipose cells. What the significance of this condition may be the writer is not able to say, but since the structure of this region of the gastric mucous membrane is not clear no attempt will be made to describe its appearance under higher magnification than was employed in the figure above. However, as will be noted below, there is probably no great



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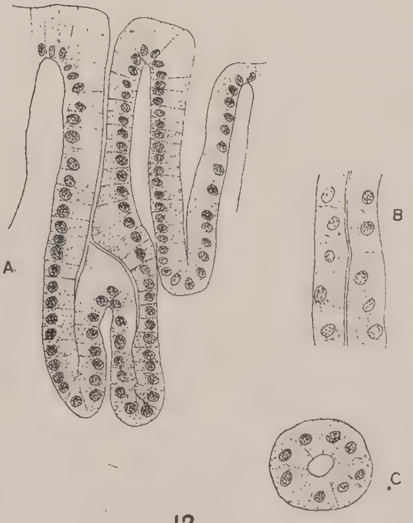

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Fig. 11 A transsection through the wall of the pyloric region of the stomach of the feeding animal, under low magnification; *m*, mucosa; *om*, oblique muscles; other letters as in figure 8.

Fig. 12 The glands of the middle or fundic region of the stomach of the hibernating animal, under high magnification; *A*, through duct; *B*, through body of gland; *C*, through fundus of gland.

difference between the pyloric mucosa and that of the other regions of the stomach.

Figure 12 shows portions of typical glands from the mucosa of the middle region of the stomach, the posterior border of the large stomach cavity; *A* is a longitudinal section through two ducts where they open to the surface; *B* is a similar section through the body of a gland below the region of the duct; *C* is a transsection through the bottom or fundus of a gland; all are drawn with a camera under the same magnification.

As is seen in figure 11, under low magnification, the duct is about one-third of the entire length of the gland. The lumen of the duct is fairly wide, that of the body of the gland is reduced to a mere slit, while that of the fundus is quite wide.

One, two, or possibly more, glands may open to the surface through one duct, as is shown in figure 12. There is nothing peculiar about the epithelium of these glands. Near the opening of the duct the cells are of a typical columnar character, with finely granular cytoplasm, each with a nucleus at its basal end.

In the deeper parts of the duct the cells become shorter until in the body of the gland (fig. 12, *B*) they are cuboidal in outline.

The bodies of the glands are so closely packed together that it is difficult to pick out an individual tube that will show details clearly enough to draw with a camera lucida. So far as could be observed all of the cells of this region of the gland are alike.

The bottom or fundus of the gland, as seen in figure 12, *C*, is somewhat enlarged and has a wide lumen. The cells are of the same general character as in the more distal parts of the gland except that they are somewhat more columnar or pyramidal than in the body of the gland. The nuclei of the body and fundus are usually somewhat larger and more nearly spherical than in the columnar cells of the duct.

The feeding animals from which tissues were taken were considerably smaller than the hibernating specimen, so that the stomach walls were proportionately thinner; but, so far as could be discovered, there was no difference in structure.

The relative thickness of the entire wall in each of the three regions sectioned was about the same as described above.

As has been said, the mucosa of the pyloric or small region of the stomach from the hibernating animal was so poorly fixed that its structure could not be made out. In the feeding stage the mucosa of this region was as well fixed as any of the other tissues and showed that its structure is essentially like that shown in figure 12, except that the glands are proportionately not quite so long as in the fundic and cardiac regions, and are somewhat more open—that is, they have wider lumina; their lining cells are all of one kind and are unchanged from what was seen in the hibernating condition.

THE SMALL INTESTINE

Three regions of the small intestine will be described: (1) an anterior, just caudad to the stomach; (2) a middle; and (3) a posterior, one-half inch cephalad to the rectum or large intestine (fig. 1).

As might be expected, the general structure of the wall of the intestine is essentially the same in all three regions, the slight differences noticeable being due mainly to variations in the thickness of the various layers.

The middle and posterior regions have about the same diameter, while the diameter of the anterior region is considerably greater, due partly to the greater diameter of the lumen but mainly to the greater thickness of the constituent layers, especially the mucosa. The mucosa is also thrown into more numerous and complicated folds in the anterior than in the middle and posterior regions; the complexity of the mucosa seems to diminish as the intestine is followed caudad. In the anterior region the mucosa may form at least one-half of the entire thickness of the wall, while in the posterior region it may form less than one-third of the thickness of the intestinal wall. The minute structure of the intestinal epithelium will be described below.

The chief peculiarity of the intestinal wall is the apparent total absence of a submucosa (fig. 13). As will be described later, the mucosal epithelium is laid upon the usual bed of fibrous and lymphatic tissue, the tunica propria (fig. 13, *tp*).

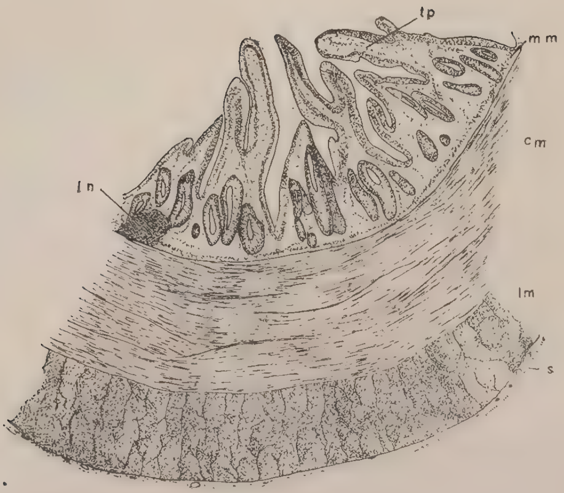
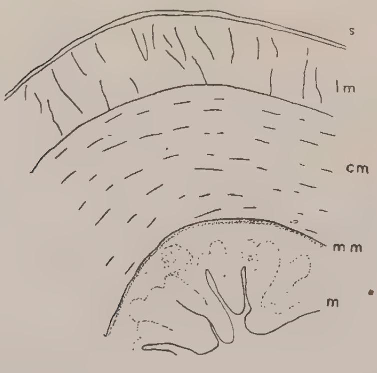


Fig. 13 A transsection of the wall of the anterior region of the small intestine of the hibernating animal, under low magnification; *ln*, lymph node; *tp*, tunica propria; other letters as in figure 8.



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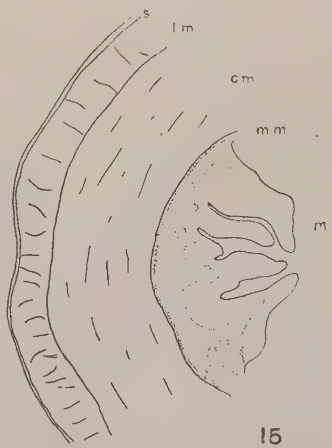

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Fig. 14 An outline of a transsection of the wall of the middle region of the small intestine of the hibernating animal, under low magnification; lettering as in figure 8.

Fig. 15 An outline of a transsection through the wall of the posterior region of the small intestine of the hibernating animal, under low magnification; lettering as in figure 8.

At the outer border of the tunica propria, and with no tissue corresponding to a submucosa between it and the circular muscular layer, is a thin and indistinct layer that has the appearance of a longitudinal layer of muscle fibers; this should correspond to the muscularis mucosa (figs. 13, 14, 15 and 17, *mm*).

The circular, *cm*, and longitudinal, *lm*, muscle layers are compact, and are distinct from the other layers of the wall; the former is approximately twice the thickness of the latter. The relative thickness of all the layers in the three regions of the intestine may be seen by comparing figures 13, 14 and 15.

The serosa, *s*, which is of about the same character in the three regions under discussion, is a distinct and fairly dense layer of connective tissue with numerous blood vessels.

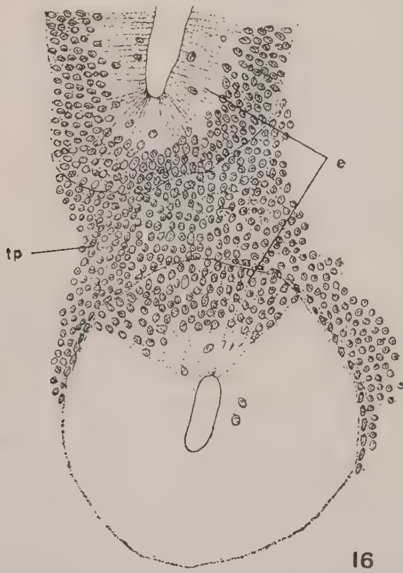
The general appearance of the mucous membrane as a whole is sufficiently clear in the low-power drawing described above, so that all that need be shown under a higher magnification is the epithelium (fig. 16). The upper part of this figure represents the lower end of one of the intestinal glands cut longitudinally, below which is the end of another gland in transverse section. Between the two sections is the compact tunica propria of lymphatic tissue.

The section from which this particular figure was drawn was in the anterior region, but the corresponding part of a section in either of the other regions would have practically the same appearance.

The epithelium is of the stratified columnar type. The superficial cells are very tall and narrow, with the nuclei generally at or near the bases, though an occasional nucleus may be seen near the free end of a cell. Below the tall columnar cells are four or five rows of nuclei which represent smaller, irregular cells, though the cell walls could not always be determined between the closely packed nuclei. No goblet cells are to be seen at any place.

The relative diameters of the three regions of the small intestine in the feeding condition are about the same as noted for the hibernating stage; that is, the anterior region has the greatest diameter and the other regions are smaller and have about the same average diameter.

The most marked difference between the intestine during hibernation and feeding is in the relative thickness of the mucosa and muscular layers. As described for the hibernating stage, so in the feeding stage, the mucosa is relatively the thickest in the anterior regions and diminishes in thickness caudad; but while, in the hibernating stage, it forms, in the anterior region, as much as half of the entire thickness of the wall, in the feeding condition it forms, in the same region, at least two-thirds of the entire wall and in the middle and posterior regions more than half of the wall.



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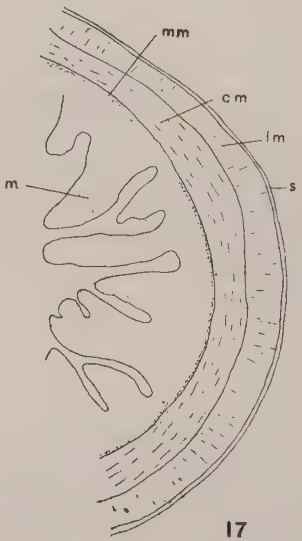

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Fig. 16 Part of the mucous membrane of the anterior region of the small intestine of the hibernating animal, under high magnification. The upper part of the figure shows a part of a gland cut longitudinally, the lower part of the figure shows another gland cut transversely; *e*, epithelium; *tp*, tunica propria.

Fig. 17 An outline of a transsection of the wall of the middle region of the small intestine of the feeding animal, under low magnification; *m*, mucosa; other letters as in figure 8.

The feeding animals being the smaller, the diameter of the intestine was considerably less than in the hibernating stage;

but the actual thickness of the mucosa was practically the same, so that the difference in diameter was due to the difference in the thickness of the muscular and fibrous layers. It is therefore probable that the differences noted above are due rather to the differences in the size of the animals from which the tissues were taken than to the different conditions of hibernation and feeding. The point to be noticed is that the increase in the diameter of the intestine is due almost if not entirely to an increase in thickness of the connective tissue and muscle layers.

No difference in the complexity of the folds of the mucosa of the two stages can be noticed.

The thickness of the fibro-muscular part of the wall of the intestine varies considerably on different sides of the same region, but it consists of the same layers in about the same relative amounts.

Figure 17 represents in outline the wall of the middle region of the small intestine during feeding.

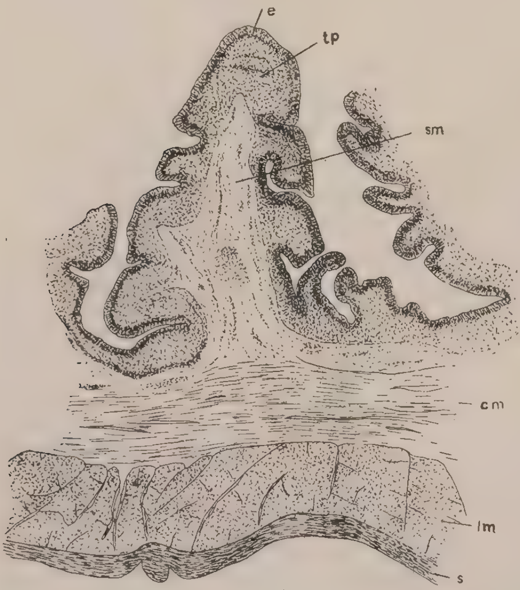
The epithelium is of the same thickness in the two stages, and the only difference in its character that can be seen under a high magnification is that, in the middle region at least, the nuclei are not crowded so close together at the basal ends of the cells as in the hibernating stage but are scattered more towards their free ends.

Altogether, the differences in microscopic structure between the small intestine of an alligator at the end of the hibernating period and at the end of a period of regular feeding are very slight.

THE RECTUM

The planes of the two sections studied are shown in figure 1; a low-power drawing of the posterior region is shown in figure 18. The anterior and posterior regions of the rectum do not differ from each other sufficiently to make it worth while to represent both by drawings. Had an entire section through either region been drawn it would be seen that the wall is of very different thickness in different places, as was noted in connection with the small intestine; the posterior section was drawn where the wall was thin.

It might be supposed that in the feeding season the fecal matter in the posterior region of the rectum would stretch the walls sufficiently to obliterate largely the prominent folds seen in figure 18, but such does not seem to be the case. The usual layers of the vertebrate intestine are present.



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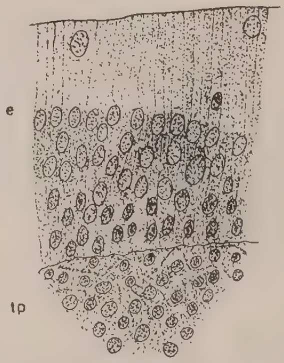

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Fig. 18 A transsection of the wall of the anterior region of the rectum or large intestine of the hibernating animal, under low magnification; *tp*, tunica propria; other letters as in figure 8.

Fig. 19 The epithelium of the anterior region of the rectum of the hibernating animal, under high magnification; *e*, epithelium; *tp*, tunica propria.

The epithelium, shown under high magnification in figure 19, is of the same character and thickness throughout, except that as the cloacal aperture is approached the columnar epithelium changes into the stratified variety. It consists of very tall and narrow columnar cells apparently in one layer, though it is difficult to be sure of this. With an occasional exception, near the top, all of the nuclei are arranged in a fairly wide zone below the middle of the epithelium. The nuclei are oval in shape and lie so close together that it is difficult, as has been said, to be sure that the cell to which each belongs extends throughout the entire thickness of the epithelium.

Beneath the epithelium (fig. 18, *e*) is a dense tunica propria, *tp*, underlaid, in turn, by the muscularis mucosa, *mm*, and a submucosa, *sm*, of the usual character, which is thrown into marked folds. The circular, *cm*, and longitudinal, *lm*, layers are of the usual character except that they vary more in thickness, as noted above, and in density than is usually the case.

The serosa, *s*, is comparatively thin and compact in both regions, and varies somewhat in thickness at different places.

The rectum of the feeding animal was sectioned in the same regions as in the hibernating. As has been said, the feeding animals used were much smaller than the hibernating, so that, as might be expected, the diameter of the rectum was much less in the former than in the latter. Except for this difference in diameter there was no noticeable difference between the two stages. In the case of the small intestine, it will be remembered, the greater diameter of the intestine of the larger animal was mainly due to the greater thickness of the muscular and connective tissue layers and not to any increase in thickness of the mucous membrane. In the rectum the mucosa varies in thickness in the animals of different size as do the other layers of the wall.

The glandular character of the lining of the rectum seems to indicate that this region of the intestine must have some digestive or absorptive function and that it does not act merely as a receptacle for fecal matter; this makes it all the more strange that there should not be some change produced in its structure by five or six months of feeding or of fasting.

SUMMARY

The material used in this investigation was taken from young animals at the end of a feeding period of about five months, and towards the end of the hibernating period after fasting for four or five months.

The regions of the enteron that were studied were as follows: the tip and base of the tongue; the anterior and posterior regions

of the roof of the mouth; the anterior and posterior regions of the esophagus; the cardiac, fundic, and pyloric regions of the stomach; the anterior, middle, and posterior regions of the small intestine; the anterior and posterior regions of the rectum. Since the work was started at the end of the hibernating period, the tissues of that period were studied and drawn first.

The only difference between the structure of the tip of the tongue during hibernation and during the feeding season is that the scaly epithelium with which it is covered is somewhat thicker and more compact in the former than in the latter condition, though even this difference may have been due to differences in the ages of the animals used. The base of the tongue differs from the tip in having a thicker epithelium and in having compound tubulo-alveolar glands. These glands in the hibernating animal have many more alveoli than in the feeding animal, though this, again, may have been due to the difference in age.

The lining of the roof of the mouth is essentially the same as that of the tongue. The glands are found only in the posterior region. The slight differences in the papillae here found may easily be due to the difference in age.

The oesophagus shows the usual layers for that region. Its epithelium is partly ciliated in the anterior part. The muscularis mucosa is very scant in the anterior region. The only difference between the two stages is that in the feeding the muscularis mucosa in the anterior region is much more strongly developed than in the hibernating stage; and in the former the nuclei of the epithelium are not arranged in two zones as in the latter.

The stomach has the usual layers, and has essentially the same structure in the three regions studied, except that the wall in the fundic region is much the thickest, due mainly to the great thickness of the middle muscle layer. Only one kind of cell is found in the gastric glands. No difference is to be noted between the hibernating and feeding conditions.

The chief peculiarity of the small intestine is the apparent entire absence of the submucosa. Goblet cells are also wanting. The greater diameter of the anterior region is due both to the greater diameter of the lumen and to the greater thickness of the walls. The middle and posterior regions have about the same diameter, though the mucosa becomes thinner and less complicated caudad. There is practically no difference between the hibernating and feeding stages.

The anterior and posterior regions of the rectum have essentially the same structure. No difference can be seen between the hibernating and feeding conditions.

BIBLIOGRAPHY

Chaffanjon, M. J. 1881 Observations sur l'alligator Mississipiensis. Annales de la Soc. Linn. de Lyon, tom. 28, pp. 83–96.

Eisler, P. 1889 Zur Kenntniss der Histologie des Alligatormagens. Archiv f. Mik. Anat., Bd. 34, pp. 1–10.

Reese, A. M. 1910 The development of the digestive canal of the American Alligator. Smithsonian Miscellaneous Collections, vol. 56, no. 11, pp. 1–25.

Smallwood, W. M., and Rogers C. G. 1911 Effects of starvation upon Necturus maculatus. (Preliminary report). Anat. Anz., Bd. 39, pp. 136–142.

INNERVATION OF AN AXILLARY ARCH MUSCLE

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ONE FIGURE

In the course of a dissection of the left axillary space of a well developed white male infant dying a few days after birth, an axillary arch muscle was found. The only nerve entering the muscle was a fair-sized twig of the lateral branch of the third intercostal nerve. This twig entered the ventral margin of the muscle about 5 mm. distal from its origin, passed transversely and dorsally through it and terminated in the fascia and panniculus adiposus of the axillary floor. The first third of the course of the nerve within the muscle was relatively superficial, being distinctly visible through a thin semitransparent lamina of fibers overlying it, the rest of its course was more deeply placed. In the middle of the visible part a small fasciculus emerged at nearly a right angle and ran distally in line with the muscle fibers for about 2 mm. when it sank into the muscle substance.

The usual innervation of these axillary skin muscles, when present in the human being, is stated to be the anterior thoracic nerves, lateral or medial or both, and occasionally the intercostobrachial. In the literature at hand, I find no mention of an innervation in man from as low a segment as the third dorsal. The instance here reported may, therefore, be an addition to our knowledge, as it is to our statistics on the subject. According to Wilson,[1] in a recent article on the subject, Kohlbrügge states that in semnopitheci the axillary skin muscles are normally supplied by the lateral ramus of the second or third dorsal nerve, and that for so stating he was vigorously criticised by both Tobler and Ruge.

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[1] J. T. Wilson, The innervation of the Achselbogen muscle. Journal of Anatomy and Physiology, vol. 47, October, 1912.

It appears also from Wilson's article that his own researches on the innervation of the axillary arch muscle, resulting in finding it supplied by the anterior thoracic nerves, directly or indirectly, and in some instances by the intercostobrachial, had been the subject of adverse criticism by the same authorities.

It was having in mind Wilson's article on the innervation of the axillary arch muscle that led me, upon discovering the muscle in the present case, to make a careful dissection and examination of its innervation. The discovery of the arch was made very early in the dissection, and in such manner that it would appear unlikely any destruction of its nerve supply could have occurred: the pectoralis major had been cleaned, the fascicles of the anterior thoracic nerves entering it secured, the muscle divided near its insertion and reflected, the subjacent tissues and structures undisturbed. In cleaning the lateral extremity of the pectoralis near its insertion, which was the next step in the dissection, the insertion of the axillary arch muscle was observed. From this point onward, the dissection was specially carried on to ascertain what the innervation of the arch in this case would be, with the result as here reported.

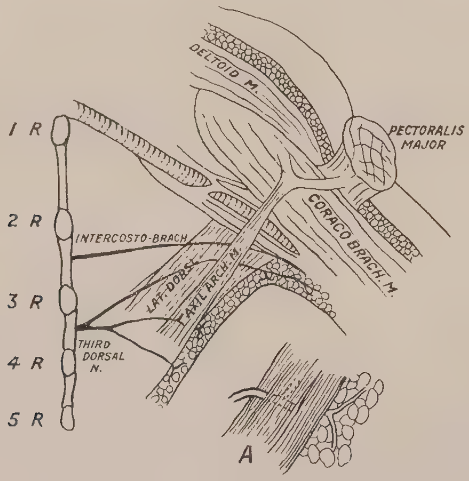

Fig. 1 Showing axillary arch muscle supplied by branch of lateral division of third dorsal nerve. *A* shows enlarged view of nerve at point of entrance into axillary arch muscle.

ABERRANT PANCREAS IN THE SPLENIC CAPSULE

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ONE FIGURE

This interesting anomaly was first encountered during the microscopical examination of material taken from autopsy at the Philadelphia Hospital. Grossly nothing was seen to suggest the above condition. The specimen was from a colored woman of twenty-one, dead of general peritonitis following a suppurative endometritis. Degenerative changes were found in the viscera secondary to a severe general toxemia, severe enough to produce fatty degeneration in the liver. There were no signs of neoplasm.

On holding the microscopic section to the light a semi-circular section is seen whose convex border is covered by a distinctly thickened capsule. Under the lower powers of the microscope the pancreatic elements are the first structures to attract our attention. They lie in a quite thick capsule whose deeper layers consist of densely arranged connective tissue fibrillae. As the surface is approached the fibrillae become more loosely arranged and contain few nuclei. These nuclei are of young type. In places a serosa can be traced, but this is masked in many places by bands of fibrin, leucocytes and red blood cells which lie just outside the capsule and bespeak the general fibrinous peritonitis found grossly.

All through the capsule, for the most part in the superficial half, but to no small degree lying also in the deeper layers, we note the foci of pancreatic cells. Many are arranged as ducts, both small and large, lined by low columnar epithelium, both isolated and in groups. Many contain small masses of pink granular material but none are dilated. Along with the ducts, but for the most part separated from them by fibrous tissue, are most typical islands of Langerhans. They appear both independently in the fibrous tissue and in the midst of the pancreatic acini. These acini are composed of cells which have large vesicular nuclei, whose protoplasm is abundant and richly staining. In most cases they are found in groups of twenty or thirty, but in a few cases only three or four are associated.

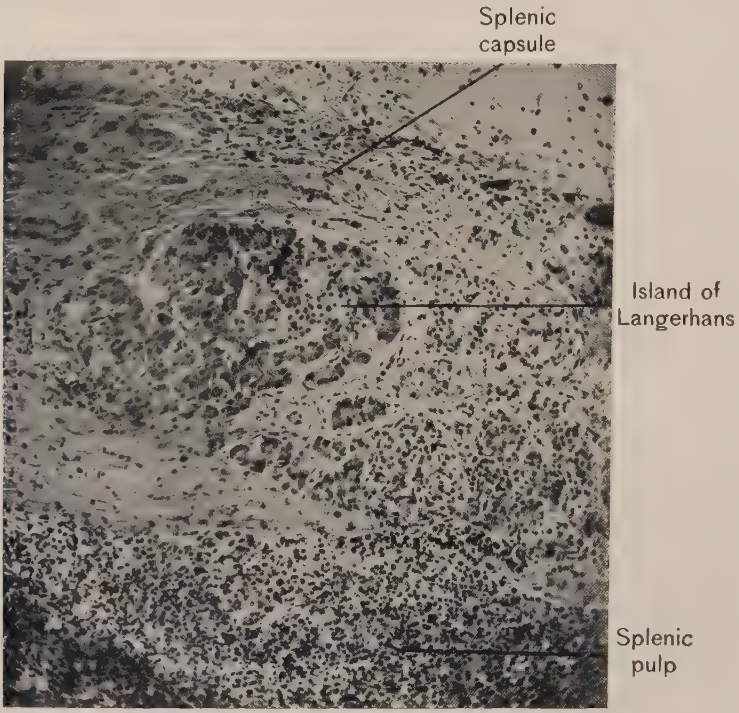

Fig. 1 Section from capsule of accessory spleen

One group deserves especial mention. It extends from the surface of the capsule into the splenic pulp. Between these two structures, pancreas and spleen, there is no connective tissue whatsoever, the lymphocytes of the splenic pulp being directly apposed to the pancreatic cells. In several places, too, there are focal collections of lymphocytes, in one particular place especially dense around a small arteriole, as if to simulate Malpighian follicles.

In view of the close anatomical relations existing between the pancreas and spleen it is natural to suspect adhesions of these organs. The only other way to explain this phenomenon is upon the ground of faulty development, assuming a diversion of the embryonal pancreatic cells from their accustomed route.

To disprove adhesions we have the following facts: No mention of adhesion is made in the gross notes. The microscopical appearance, too, belies adhesion. The upper layers of the capsule are smooth, except for slight fibrinous exudate resulting from the general peritonitis. The fibers are not torn. No pancreatic cells are present outside the capsule such as should be present in adhesion. This is not a case of cellular inclusion in old fibrous adhesion, since the cells are not atrophic as they should be from pressure of old adhesion. The deep position of some of the groups (even breaking into the splenic parenchyma) precludes the possibility of its being a case of chronic adhesion.

In line with this case, Dr. Allen J. Smith very kindly furnished me with a section of a guinea-pig's spleen in which a few tubules appeared at the juncture of the splenic pulp and its attachment to the parieties. They were lined by a tall simple columnar epithelium and contained globular pink staining masses of secretion. It is impossible to state their nature, whether the ducts of pancreatic or intestinal glands. They were certainly aberrant.

Warthin in 1904 was able to collect forty-nine cases, two of which were his own, so the variation is not uncommon. The first case reported was by Klob, who quotes Leydig. The latter states that in certain animals the pancreas occurs normally in separate portions. Thus, in the mole, lobules are found distinctly removed from the main organ, and only connected to it by blood vessels—no ducts. In pelobates parts of the pancreas are found in the walls of the stomach. In the salamander these are regularly found in the walls of the jejunum.

To Warthin's cases I am able to add nineteen, as follows:

CASE NO.	YEAR	REPORTED BY	LOCATION AND SIZE	MICROSCOPIC APPEARANCES	EXCRETORY DUCT
1	1901	Gandy and Griffon	First part of duodenum; size of a franc in all three coats	Many large excretory ducts, numerous smaller ducts; typical pancreatic acini and islands of Langerhans	Not mentioned
2	1904	Reitman	Wall of ileum, 10 cm. above ileo-cecal valve; 2.5 x 0.75 cm.	Centro acinar cells and islands of Langerhans present	Not definitely mentioned
3	1904	Reitman	Duodeno-jejunal flexure 2 x 1 cm.	Like pancreas	
4	1904	Turner	Jejunum, 30 cm. from duodenum circular 8 mm. in diam., 3 mm. thick	No islands, no fibrosis	
5	1904	Muller	Wall of stomach, 8 cm. from pylorus, 1.5 x 2 cm. in submucosa	Islands present, dilated ducts, no fibrosis, or chr. interstitial inflammation	
6	1904	Alburger	A few cm. below beginning of jejunum, 1 cm. in diam. mucosa, but also penetrates muscularis	Islands present, dilated ducts present and interstitial fibrosis; no inflammation	Probable
7	1904	Robinson	Wall of ileum		
8	1904	Longcope	Jejunum; size of almond		
9	1904	Stengel	Duodenum		
10	1904	Bize	Tip of diverticulum of ileum, 25 cm. from ileo-cecal valve, in muscularis, size of peanut	True pancreatic structure, centro-parietal cells, many ducts	None
11	1904	Bize	Tip of diverticulum 60 cm. from ileo-cecal valve; size of almond; in submucosa and muscularis	Dilated ducts like adenoma	Not mentioned
12	1905	Lewis	Jejunum, 0.85 cm. below pylorus, 16 x 12 x 4 mm. in muscularis	Perfect pancreas, islands and ducts present	
13	1906	Hedinger	In tip of Meckel's diverticulum, 5 x 2.5 x 5 cm.; submucosa and muscularis	Typical pancreatic tissue	Present
14	1908	Ellis	Hilus of spleen, 5 mm. in diameter	Few small interlobular ducts, acinar cells and probable centro-acinar cells; also areas resembling islands of Langerhans	
15	1908	Ellis	Posterior wall of stomach, 5 cm. from pylorus 1.5 cm. x 0.6 cm. in submucosa	No islands; many ducts centro-acinar cells; resembles adenoma with beginning malignancy	
16	1910	Weidman	Not seen grossly (capsule of spleen)	Capsule of spleen; small ducts, acini, centro-acinar cells and islands of Langerhans present	Probably none
17	1912	Max Koch	Not seen grossly	Tip of Meckel's diverticulum; islands and ducts present	
18	1912	Max Koch	Not seen grossly	Tip of Meckel's diverticulum; islands and ducts	
19	1913	McFarland	Posterior wall of stomach; greater curvature near fundus; size of half a soup bean	Islands and ducts present in submucosa	

A summary of the above results follows:

Gastric wall	3
Duodenal wall	2
Wall of ileum	2
Wall of jejunum	5
Diverticulum of ileum	2
Meckel's diverticulum	3
Hilum of spleen	1
Capsule of spleen	1

Adding these to Warthin's forty-nine cases results as follows:

Wall of stomach	17
Wall of duodenum	14
Wall of jejunum	20
Wall of ileum	3
Wall of intestine (indefinite)	1
Diverticulum of stomach	1
Diverticulum of jejunum	1
Diverticulum of ileum	6
Meckel's diverticulum	4
Umbilical fistula	1
Mesenteric fat	1
Omentum, great	1
Hilum of spleen	1
Capsule of spleen	1
	72

Out of sixty-eight cases some presented more than one aberrant nodule. These figures indicate that in nearly 80 per cent of cases the variation is found close to the duodenum. Twelve of the sixty-eight cases were in diverticula, or in about 18 per cent of the cases.

It is found, on referring to the above cases, that the size varied from 0.4 to 9 cm., the average being about the size of an almond. Most were flat discs placed in the submucosa.

The islands of Langerhans are specifically mentioned in only eighteen cases, but they were doubtless present in most of the cases of 'typical,' 'similar to,' and 'identical with' pancreases. Twenty-four of the cases showed excretory ducts opening into the gut. In sixteen cases their presence is denied, by some after careful search. The majority make no mention of them.

Round cell infiltration and fibrous overgrowth are frequently mentioned, as also pink granular material within the ducts. In several cases the ducts were distended, simulating adenomata, in Ellis's cases with beginning malignancy. He found a fibroma in the wall of the stomach, associated with aberrant pancreas. Alburger's case had multiple cutaneous lipomata.

Pathological lesions were encountered as follows: umbilical fistula, diverticulum with intussuspection,[1] necrosis and abscess formation, malignancy.

Points which, space permitting, might be considered at greater length are:

1. The bearing of this case upon Cohnheim's theory for the cause of tumors.
2. The likelihood of the duct, in my case, communicating with the duodenum.
3. Associated aberrance, in my case, of the splenic parenchyma and improper numerical relationship between the islands of Langerhans and pancreatic acini.
4. Disposition of secretion.
5. Associated tumors (lipomata in Alburger's case, adenoma maligna and fibroma in Ellis's).

To explain the position of the pancreatic elements in the spleen we must go back to the second month of fetal life. At this time the pancreas starts to develop by projecting its hypoblastic buds into the ventral and dorsal mesenteries. The spleen is first seen a month later a little higher up, but close to the dorsal pancreatic anlage. Zenker assumes that a separate anlage exists for the principal pancreas and for each accessory pancreas, if there be more than one. Warthin, on the contrary, thinks that such a condition is not necessary, that projecting buds of the sprouting pancreas are snared off by the surrounding mesoderm and carried off into aberrant situations. Adami amplifies this by stating that the cells must be so far differentiated that they have become unipotential, that is, capable of producing only one type of tissue.

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[1] Bize relates how a diverticulum has been formed *inside* the bowel. An accessory pancreas at its tip was in turn invaginated into the end of the diverticulum. He quotes a similar case of Brunners, also ending fatally.

Warthin's theory seems the more reasonable in my case because the foci are so numerous and often separated by dense bands of connective tissue,—in which case it would be necessary, according to Zenker, to assume the presence of, say, thirty or forty anlage. According to Warthin's theory separate pancreatic cells might have been pinched off by the surrounding mesodermic cells, the latter developing later into the splenic capsule with pancreatic inclusions.

Dr. Allen J. Smith has very kindly reviewed my notes and made the photomicrograph. For these courtesies I express my thanks.

BIBLIOGRAPHY

Alburger, Henry R. 1904 Proc. Path. Soc. of Phila., N. S., vols. 7 and 8, pp. 226–229.

Bize 1904 Revue d'Orthop. Par. 2 S. 5, p. 149.

Ellis, A. G. 1908 Proc. Path. Soc. of Phila., N. S. 11, no. 1, le 25.

Gandy, C., and Griffon, V. 1910 Bull. et Mem. de la Soc. Anat. de Paris, Anne 76, no. 7, le 451.

Hedinger 1906 Corr. Bl. f. Schweiz. Aerzte, Basel, Bd. 36, p. 395.

Klob, Julius 1859 Zeitschrift d. k. K. Gesellschaft d Aerzte zu Wien Bd. 15, S. 732.

Koch, Max 1912 Abstract from Centralbl. f. allg. Path. u. Path. Anat., le 904.

Lewis, P. A. 1905 Medical and Surgical Reports, Boston City Hosp. le 172.

Leydig 1857 Histology des Menschen und der Thiere, S. 363.

Longcope, W. T. 1904 Proc. Path. Soc. of Phila., N. S., vols. 7 and 8, pp. 226–229.

McFarland, J. 1913 Proc. Path. Soc. of Phila., January.

Muller, G. P. 1904 Proc. Path. Soc. of Phila., N. S., vols. 7 and 8, pp. 226–229.

Reitman, K. 1903 Anat. Anz., Bd. 23, pp. 155–157.

Robinson, G. C. 1904 Proc. Path. Soc. of Phila., N. S., vols. 7 and 8, pp. 226–229.

Stengel, A. 1904 Proc. Path. Soc. of Phila., N. S., vols 7 and 8, pp. 226–229.

Turner, G. G. 1904 London Lancet, vol. 2, p. 1566.

Warthin, A. S. 1904 Physician and Surgeon, Ann Arbor and Detroit, p. 337.

Zenker, F. E. 1861 Virchow's Archives, Bd. 21, S. 369.

BOOK REVIEW

Leonardo da Vinci Quaderni d'Anatomia. Edited by Ove C. L. Vangensten, A. Fonahn and H. Hopstock. Parts I and II, Jacob Dybwad, Christiania, 1912.

It has long been known, from statements made by Vasari, that Leonardo da Vinci had contemplated the writing of a book on Human Anatomy and had made for its illustration numerous drawings from dissections prepared by his own hand. On his death these drawings and the notes that accompanied them passed into the hands of a Milanese gentleman, Francesco da Melzi, but thereafter their history becomes obscure. During the reign of George III Dalton, who was at that time in charge of the Royal Library at Windsor, chanced upon a number of sheets covered with anatomical sketches and notes by Leonardo, which were apparently the manuscripts mentioned by Vasari. Investigation showed that they had been presented to Charles II, probably by the then Earl of Arundel, who had been Ambassador to the court of the Emperor Ferdinand II of the Holy Roman Empire, and having been deposited by the king in the Royal Library they had remained there, forgotten, until rediscovered by Dalton. But even then they attracted but little attention, notwithstanding the praise bestowed upon them by William Hunter, to whom they were shown by Dalton, and it was not until 1883 that their existence became generally known by the publication in that year of J. P. Richter's The Literary Works of Leonardo da Vinci, in which some quotations of the notes accompanying the sketches were given.

A little later, when the interest in the literary and artistic remains of Leonardo, now so manifest, had developed, a facsimile reproduction of sixty of the sheets in the Windsor collection was published by Sabachnikoff and Piumati in two beautiful volumes, which contained also a transcription of the manuscript notes and a French translation of them. These volumes appeared in 1898 and 1901 and the second contained a promise that other volumes containing reproductions of the remaining sheets would follow. This promise has, however, remained unfulfilled, possibly because there also appeared in 1901 facsimiles of nearly all the sheets in the collection in ten volumes, edited by Rouveyre. This edition lacked, however, a transcription and translation of the notes and thereby was far from satisfactory, since the crabbed chirography of the fifteenth century, the uncertainty of Leonardo's orthography and, above all, his habit of writing from right to left, makes the translation of the notes from the facsimiles a most arduous task for the ordinary reader.

Under these circumstances the necessity for an edition that would contain all the Windsor folios without exception and at the same time give an accurate transcription and translation of the notes appealed to Dr. H. Hopstock, Prosector in Anatomy in the University of Christiania, and having obtained permission to photograph and publish the manuscript through the kind offices of Her Majesty Queen Maud of Norway and having secured as collaborators Dr. A. Fonahn, Professor of the History of Medicine, and Ove C. L. Vangensten, Professor of Italian, both of the University of Christiania, the work was begun in 1910 and the first two volumes are now before us.

The first volume contains the reproductions of thirteen of the original folios and the second those of twenty-four, each facsimile being accompanied by an accurate transcription of the manuscript notes together with their translation into English and German. Nothing but praise can be given the editors for the care and accuracy with which they have accomplished their task and they are to be congratulated on the manner in which the publisher also has fulfilled his part of it, the beautifully clear reproductions, the excellent letterpress and the entire appearance of the volumes being fully worthy of the important subject matter.

The sketches and notes of the first volume are somewhat varied as to subjects, but for the most part bear upon the mechanism of respiration, including the action of the diaphragm, and, to a certain extent, upon the heart, while those of the second volume are very largely concerned with the structure of the heart. Some additional sketches of the heart are promised in a later volume and those on the reproductive organs will appear in the third volume, which may be expected during the present year.

A detailed account of Leonardo's Anatomy, as revealed by the volumes before us, would be out of place here; it must suffice to say that his physiology was essentially Galenic and so too his Anatomy, the latter, however, not the Galenic anatomy of the Middle Ages, but a return to the truer anatomy of the classical Galen. But while one cannot concede to Leonardo any important advance in anatomical knowledge beyond that possessed by Galen, in estimating his position in the history of anatomy it is not with Galen that he is to be compared, but with his own more immediate predecessors and contemporaries. His manuscripts are to be assigned to the beginning of the sixteenth century, one of the folios reproduced in the second volume before us bearing the date 1513, and when his figures are compared with those of Ketham (1491), Peyligk (1499), Hundt (1501), Reisch (1504), Phryesen (1518) or Berengarius (1521), they reveal, apart from their artistic superiority, a preëminence in accuracy and careful observation that fully confirm William Hunter's estimate of him as "by far the very best anatomist and physiologist of his time."

Leonardo's projected treatise on anatomy was never written, so far as is known, and it is difficult, therefore, to estimate his influence on the revival of anatomy. One can hardly avoid a suggestion that Vesalius may have known of his work and have been influenced by it, although no evidence in favor of such a suggestion has as yet been advanced. And, after all, both Leonardo and Vesalius were products of the Renaissance, when men began to throw off the shackles of tradition and to observe and think for themselves. Nowhere more clearly than in Leonardo's notes can one perceive the spirit of the age. They record observations made and to be made, propound questions as to the significance of parts, and explanations of their action and discuss other probabilities, frequently meeting possible objections from hypothetical opponents. They are full of the spirit of modern science, which, after all, was the spirit of the Renaissance, and in them one can find abundant material for the study of the psychology of that most interesting period in the evolution of modern thought. It is not anatomists alone who owe a debt of gratitude to the editors of these splendid volumes; all students of the Renaissance are equally indebted with them, and all who have had the privilege of studying these first two volumes will join in a sincere wish that it may be possible to complete the reproduction of the remaining Windsor folios at an early date and in the same thorough manner.

J. P. McM.

THE GROWTH OF THE DRY SUBSTANCE IN THE ALBINO RAT

LAWSON GENTRY LOWREY

The Anatomical Laboratory of the University of Missouri

FOUR FIGURES

Work upon growth which involves more than the recording of the body weight at certain intervals and the study of the averages obtained from a large number of such weights is of very recent date. It is not surprising, therefore, that the literature contains so few data on the growth of the dry substance. It is true that there are scattered data which have been collected and utilized for comparison in this paper, but with the exception of the central nervous system of the white rat, carefully studied by Donaldson and his associates, there are no extensive records for any species. The available published data usually refer to the *water* content rather than to the dry substance. Since the *relative* changes are greater for the dry substance, however, the data in this form are preferable for graphic representation in curves of relative growth. As growth and differentiation proceed, among other changes there is an alteration in the relative amounts of water and of dry substance. It is the purpose of this paper to present some data concerning the nature and extent of this alteration for the skin, skeleton, musculature, viscera and entire body of the albino or white rat during postnatal development.

MATERIAL AND METHODS

Observations on 62 white rats (Mus norvegicus albinus) furnish the data presented in this paper. These rats are divided into groups as follows: 12 (6 m.–6 f.) at birth (or within 24 hours); 10 (4 m.–6 f.) at one week; 9 (4 m.–5 f.) at twenty days; 10 (5 m.–5 f.) at six weeks; 9 (5 m.–4 f.) at ten weeks; 10 (5 m.–5 f.) at

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five months (150 days); 2 males approximately one year old, the exact age being unknown.

With the exception of one of the old rats, which was secured from Chicago, the rats were all reared in the laboratory. They represent healthy, well nourished rats. Some of the old showed traces of a lung infection, but none are included here in which the infection was sufficient to impair the health or vigor of the animals. The method of feeding and the reasons for the selection of the ages at which the observations were made have been stated in a recent paper (Jackson and Lowrey '12).

The method of observation may be summarized as follows: the animals were chloroformed (usually taken before feeding in the morning); the trunk (nose-anus) and tail lengths and the body weight were recorded. The head was removed just anterior to the larynx and just posterior to the foramen magnum. The body was suspended and the escaping blood caught in a container while the head was weighed and the brain and eyeballs removed. The spinal cord, thyreoid, thymus, heart, lungs, liver, spleen, stomach and intestines with mesentery, suprarenals, kidneys and gonads were carefully removed and placed with the brain and eyeballs in a moist chamber. The skin, including ears and claws, was removed: this and the skeleton and musculature—from which the remaining parts (trachea and larynx, oesophagus, genitalia, large vessels and all dissectible fat) had been removed and placed with the blood—being also placed in a moist chamber. Evaporation was in this way reduced to a minimum. The individual organs, or, in some cases, certain combinations of the small organs (as the suprarenals, thyreoid, spleen and gonads in the newborn) were carefully weighed in a closed glass vessel. Where the organs were large enough, they were weighed to 0.001 gram (1 mg.), but where they were so small that variations of 1 mg. made an appreciable difference in the weight, they were weighed to 0.0001 gram (0.1 mg.). This is sufficiently accurate for the larger organs, but not for the smaller, which were therefore grouped together. The skin was weighed, then the skeleton and musculature together.

The muscle was then carefully removed and the skeleton, including bones, cartilages, teeth and ligaments, was weighed. This weight, subtracted from the weight of the combined skeleton and muscle, gives the weight of the muscle and tendon. The stomach and intestines were opened and cleaned of their contents and then reweighed.

By subtracting from the recorded body weight the weight of the intestinal contents and the estimated contents of the urinary bladder (if any) we secure the net weight. All percentage figures in this paper referring to the body weight are based on this net weight.

All the observed structures (the various viscera, the skin, skeleton, muscle and the remaining parts designated collectively as the 'remainder') each in a separate container, were placed in an oven heated to a constant temperature of about 95°C., and there remained until they reached a constant weight. This method of abstracting the water has some points of danger, but is much more rapid than the method of desiccating in a vacuum over sulphuric acid at room temperature. According to Donaldson ('10) there is no essential difference in the results attained by the two methods. Therefore the method used was selected on account of the ease of manipulation. Before the final weighings, the various structures were cooled in a desiccator over sulphuric acid.

The technique used is faulty at one point, namely, that the observed structures were not placed in a *closed* weighing vessel at once upon their removal from the body, but were placed in a moist chamber, later weighed and then transferred to an open 'homeopathic vial' or other open vessel of suitable size in which they underwent desiccation and final weighing. Probably little or no error occurs in the fresh weights; this can not be said with equal certainty for the observations on the dried material. The air in the balance case was kept as dry as possible, but there can be little doubt that outside conditions of humidity affected the humidity within the balance case and may thus have been the cause of some abnormal variation of the dry weights. However, it is probable that no serious error results from this cause.

The number of observations is small, on account of the large amount of labor involved in collecting the data. However, the results agree fairly well and, although caution must be exercised in drawing conclusions, they give at least a general idea of the changes in the relative proportions of water and dry substance.

Except in the newborn lot, where observations were made on the whole body of three invidivuals, the weight of the dry body was obtained by addition of the observed dry weights for all structures. Care was used to dry every part of each animal, and the loss was slight in any case. The weights for the 'visceral group' were secured by addition of the weights of the individual viscera, including the small organs weighed together.

For economy of space, the observations have been condensed into a single table (table 1). This gives, for each of the structures reported, the number of observations, average fresh weight, and the average with range (minimum and maximum) of percentage of dry substance for each group. Table 4 is also based on these observations and gives for each group the number of observations, the average dry body weights, and the average and range (minimum and maximum) of relative weights of the skin, skeleton, musculature, viscera and 'remainder' in per cent of the dry body weight. The individual data will be deposited in The Wistar Institute of Anatomy, Philadelphia, whence they may be obtained if desired.

With the exception of the interval between the five months and one year groups, the intervals between the various age groups are drawn to scale in figures 1 to 4. The curve in the unscaled area is represented by a broken line.

THE DRY SUBSTANCE OF THE SYSTEMS

The skin: table 1; figure 1

As has been shown in a recent paper, the fresh skin shows a marked increase in relative weight during the first week of life (Jackson and Lowrey). At the same time, the dry substance of the skin increases from an average of 12.3 per cent of the fresh body weight at birth to 23.4 per cent at one week. In all the later groups, the fresh skin decreases in relative weight until, at one year, it forms 17.95 per cent of the body weight. At twenty days, when this decrease in relative weight has begun, the skin contains about 41 per cent of dry substance; at six weeks, 37.1 per cent, increasing then to 45.5 per cent at one year. These figures include a variable and unknown amount of fat. During the early period of increase in relative fresh weight, the skin has less than 25 per cent of dry substance; later, when the relative fresh weight is decreasing, about 40 per cent of dry substance.

No satisfactory explanation can be given at present for the observed exceptional increase in dry substance at twenty days (fig. 1). The hairy coat is well developed at three weeks, which would tend to increase the percentage of dry substance, but there seems to be no unusual fat content. In general, the great fluctuations in the percentage of dry substance in the skin are probably due chiefly to variations in the fat content.

The observations on the human skin can be reconciled only with difficulty, since some include the subcutaneous fat and others do not. Vierordt gives for the skin of a thirty-six weeks fetus 37.4 per cent of dry substance; for a newborn, 32.82 per cent (Bischoff); for the adult, 27.97 per cent (Bischoff), 28 per cent (Gorup-Besanez), or 30 per cent (Volkmann). Ohlmueller found in the skin of a fifty-six day infant 68.09 per cent of dry substance and 56.79 per cent of fat. When freed of fat, the skin contained only 26.13 per cent of dry substance. It would appear from these observations that the skin of the fetus is richer in dry substance than is the skin of the adult. This seems very improbable.

For dogs, Thomas gives data from which calculation shows that the dry substance increases from about 26.4 per cent in the skin of the newborn to about 49 per cent in that of the adult. For cats, similar data show an increase of dry substance from about 20 per cent in the skin of the newborn, to 34.5 per cent in the skin of a 22 day cat, while in an adult cat, Sedlmair found that the skin contained 47 per cent of dry substance.

The amount of dry substance in the skin of animals depends upon the balance of several factors, hair, nails or claws and particularly upon the amount of fat included. According to Vierordt, hair is composed of 87.02 per cent; nails, 86.26 per cent; connective tissue, 20.4 per cent and fat, 88.06 per cent, of substances which remain after dessication. The amount of dry

TABLE 1

Showing the average (also range of minimum and maximum) amount of dry substance in per cent of the fresh weight

GROUP	BODY (net)			SKIN		
	Number of observations	Average fresh weight	Average per cent dry substance (and range)	Number of observations	Average fresh weight	Average per cent dry substance (and range)
		grams			*grams*	
Birth......	15	4.22	11.7 (9.9–13.3)	12	0.882	12.3 (10.4–14.2)
1 week.....	10	9.05	20.1 (14.7–24.3)	10	2.175	23.4 (18.0–29.4)
20 days....	9	24.5	29.9 (28.6–32.0)	9	5.02	41.1 (38.7–44.7)
6 weeks....	10	61.3	29.5 (26.2–32.4)	10	11.037	37.1 (33.4–44.9)
10 weeks...	7	126.7	33.0 (31.3–35.4)	9	20.015	43.0 (39.1–45.0)
5 months..	10	182.4	32.2 (29.8–35.0)	10	32.20	44.2 (39.1–46.8)
1 year (?).	2	267.5	31.5 (31.1–31.8)	2	37.78	45.5 (40.9–50.1)
	SKELETON			MUSCULATURE		
Birth......	7	0.663	18.1 (16.6–20.1)	7	1.104	10.7 (9.5–11.8)
1 week.....	9	1.711	22.1 (19.4–24.3)	9	2.022	16.2 (14.1–18.5)
20 days....	9	4.087	33.3 (31.1–34.7)	9	6.40	22.6 (22.0–23.6)
6 weeks....	10	8.61	39.2 (33.4–41.9)	10	18.732	23.5 (20.9–25.8)
10 weeks...	7	14.84	45.9 (42.5–48.4)	6	51.50	25.2 (23.7–26.2)
5 months..	10	20.02	50.4 (47.6–53.9)	9	76.92	24.3 (22.7–26.2)
1 year (?).	2	23.18	52.6 (52.1–53.1)	2	125.00	23.8 (23.3–24.3)
	ALL VISCERA			EYEBALLS		
Birth......	12	0.775	15.2 (13.1–16.9)	4	0.0231	7.4 (6.52–8.36)
1 week.....	10	1.761	14.2 (10.5–15.9)	9	0.0661	10.4 (8.1 –12.0)
20 days....	9	5.09	19.1 (16.0–21.4)	8	0.1104	14.4 (13.2–15.2)
6 weeks....	10	12.17	20.7 (18.5–23.0)	10	0.1617	15.3 (13.8–16.7)
10 weeks...	9	20.90	24.4 (20.8–28.4)	9	0.207	17.0 (15.1–20.3)
5 months..	9	26.57	25.6 (22.4–28.0)	10	0.279	19.0 (16.2–19.8)
1 year (?).	2	31.75	25.1 (23.8–26.5)	2	0.340	20.15 (20.0–20.3)
	HEART			LUNGS		
Birth......	7	0.0245	13.8 (11.8–15.6)	12	0.0771	15.9 (13.4–18.5)
1 week.....	10	0.0610	14.4 (11.7–16.4)	10	0.1685	15.8 (12.2–18.2)
20 days....	8	0.1354	18.0 (16.0–19.9)	7	0.236	18.9 (17.2–21.5)
6 weeks....	8	0.4123	21.0 (20.4–21.8)	8	0.4044	19.1 (17.5–21.0)
10 weeks..	9	0.625	21.6 (19.9–22.7)	9	0.791	19.2 (16.8–20.7)
5 months..	8	0.714	21.2 (20.0–23.2)	9	1.354	19.0 (16.0–20.5)
1 year (?).	2	0.934	22.4(21.4–23.4)	2	2.806	18.4 (16.9–19.9)

TABLE 1—Continued

GROUP	LIVER			SPLEEN		
	Number of observations	Average fresh weight	Average per cent dry substance (and range)	Number of observation	Average fresh weight	Average per cent dry substance (and range)
		grams			*grams*	
Birth......	10	0.2342	19.4 (16.7–22.9)			
1 week.....	10	0.3065	20.6 (17.0–22.7)	10	0.0409	14.3 (12.5–17.5)
20 days....	9	1.200	24.3 (20.0–26.4)	7	0.0763	17.2 (16.5–20.3)
6 weeks....	10	3.541	24.2 (22.4–27.3)	10	0.273	19.8 (17.7–22.0)
10 weeks..	8	6.617	25.5 (24.5–26.2)	9	0.588	20.1 (17.8–22.5)
5 months..	9	9.236	25.7 (24.3–27.6)	10	0.666	20.6 (17.4–23.0)
1 year (?).	2	9.959	26.0 (24.4–27.7)	2	0.722	22.6 (21.6–23.6)
	KIDNEYS			TESTES		
Birth......	11	0.0384	13.3 (10.0–15.9)			
1 week.....	10	0.1230	14.5 (11.9–16.4)			
20 days....	9	0.3224	17.2 (16.0–18.6)	4	0.1063	12.9 (11.2–13.7)
6 weeks....	9	0.832	20.3 (19.2–21.1)	5	0.568	13.3 (12.9–13.6)
10 weeks...	9	1.320	20.8 (19.0–23.5)	5	1.653	12.4 (12.2–13.6)
5 months..	9	1.728	21.0 (19.1–22.5)	3	2.425	12.2 (11.6–12.8)
1 year (?).	2	2.294	22.9 (21.6–24.2)	2	2.044	13.0 (12.7–13.4)

substance will, therefore, vary with the amount of fat included with the skin and to some extent with the fatty condition of the animal. Furthermore, we should expect to find a greater amount of dry substance in the skin of a fur-bearing animal than in one not having a well developed hairy coat. This seems to be the case.

The skeleton: table 1; figure 1

The fresh skeleton, according to Jackson and Lowrey, increases slightly in relative weight during the first week, forming about 18.5 per cent of the body at seven days, and decreases thereafter to about 10.9 per cent at one year. At birth, as seen in table 1, the skeleton averages about 18 per cent of dry substance, at one week 22 per cent, at twenty days 33 per cent, and at one year 52.6 per cent. It is to be noticed that this system, which has the smallest relative fresh weight in the one year rats, has at this time the greatest relative amount of dry substance. As is the case with the skin, the dry substance during the period of increase in relative fresh weight is less than 25 per cent. The greater increase in relative fresh weight of the skin goes with a smaller content of dry substance and the greater loss in relative weight sustained by the skeleton in later stages concurs with the greater relative amount of dry substance. The change is due largely to the increase in the fat and inorganic content of the bones in the later stages.

For the human, Ohlmueller finds 37.74 per cent of dry substance in the skeleton of a fifty-six day infant and Vierodt gives 67.67 per cent of dry matter for the newborn (Bischoff), and 50(?) per cent (Volkmann) or 51.4 per cent (Gorup-Besanez) for the adult skeleton.

In two normal rabbits 186 days old, Weiske found an average of 63.2 per cent of dry substance in the skeleton. He also found that, under diets containing unusual amounts of calcium salts, the proportion of dry substance was increased. Sedlmair found that the bones of a normal cat contained 67.6 per cent of dry substance, the amount decreasing during starvation. Ohlmueller cites from Voit one young dog skeleton as containing 36.6 per cent, and an adult 55.36 per cent, of dry substance.

There is some variation among the adults of these animals, but in general there seems to be about 50 per cent to 60 per cent of dry substance in the skeleton. The differences noted at birth may be due to differences in the amount of fully developed bone present at that time, and also to differences in fat content.

There is not so much fat present in bones, therefore the variation due to varying fat content is not so great as in the case of the skin. Ohlmueller found that the fat containing skeleton of the fifty-six day infant had 37.74 per cent, and the fat free skeleton 35.19 per cent, of dry substance. According to Voit (b) the fat containing skeleton of a normal dog is 55.4 per cent and that of a starved dog 50.2 per cent, of dry substance; while the fat free skeletons contain 49.9 per cent and 48.9 per cent, respectively.

Musculature: table 1; figure 1

During the first week the fresh muscle (according to Jackson and Lowrey) decreases slightly in relative weight to a minimum of 22.8 per cent of the body, increasing thereafter to 45.4 per cent at one year. It thus shows a marked relative increase during growth. This great increase is accompanied by an increase in the dry substance less marked than has been shown for the skin and skeleton. From an average of 10.7 per cent at birth, the dry substance of the muscle increases, at first rapidly, then more slowly, to an average of 25.2 per cent at ten weeks. Thereafter a slight loss occurs and in the one year old rats the average is 23.8 per cent. The dry substance never reaches more than 27.5 per cent in any individual.

While more observations are needed to determine the accuracy of the decline in the old rats, the observation agrees with that of Ranke (quoted by Ohlmueller) that the muscles of old people are richer in water, despite the apparent dryness.

For the human, Vierordt gives 18.22 per cent of dry substance for the muscles of the newborn (Bischoff); 22.76 per cent at four years (Brubacher); and 24.3 per cent for one adult (Bischoff), 23 per cent for another (Volkmann), and 24.3 per cent for a third (Gorup-Besanez). Ohlmueller found that the fat-containing muscles of a fifty-six day infant contained 28.32 per cent of dry matter; the fat-free muscles, only 24.49 per cent.

Sedlmair finds 27.1 per cent of dry substance in the muscles of a normal cat; Forster 22.8 per cent in the fat-free and 26.1 per cent in the fat-containing muscles of a dog. Henneberg finds that the fat-free dry substance of sheep flesh increases from 18.9 per cent at seven months to about 21 per cent in adults. Petersen found in the muscles of slaughtered animals (using about 100 grams from a forequarter and a hindquarter for analysis) 21.8 per cent to 24.8 per cent of dry substance in two cattle; 20.7 per cent to 22.15 per cent in two calves; 20.01 per cent to 28.07 per cent in two hogs; 23.02 per cent to 23.32 per cent in two wethers; 23.97 per cent to 26.79 per cent in two horses.

It is apparent that differences in the amount of fat present will affect the amount of dry substance. Loss of fat may therefore explain the apparent decrease in the amount of dry substance in the old rats.

The muscle of various adult mammals seems to have about the same amount of dry substance (allowing for the influence of a varying fat content). This is not surprising, since that relationship of the various substances which most favors the physico-chemical changes of muscular contraction is likely to be the same in all.

The visceral group: table 1; figures 1, 2 and 3

The visceral group includes the central nervous system, in addition to the thoracic and abdominal viscera. The group (according to Jackson and Lowrey) increases slightly in relative weight during the first three weeks, then decreases until at one year it is relatively smaller than at birth. At birth the group contains, on the average, 15.2 per cent of dry substance; at twenty days, 19.1 per cent and at five months, 25.6 per cent. There is a slight loss in the one-week group which can not be explained, but it is probably accidental. The individual variation is slightly greater at one week, but the extremes are smaller than at birth.

The slight loss observed in the percentage of dry substance in the one year rats is possibly due to the small number of observations. It may be due to a loss of fat. It is to be regretted that there are no observations on older animals, in order to determine the changes in senility.

It is striking to find that, although the visceral group has a content of dry substance which is very similar to that of the muscle and might therefore be considered favorable to a marked increase in relative weight, this group after the age of three weeks declines steadily in relative (fresh) weight like the skeleton and the skin, although both of the latter have a much higher content of dry substance.

There are several factors which may cause variation in the percentage of dry substance in this group. They include the sum of the individual variations of the various organs and the amount of

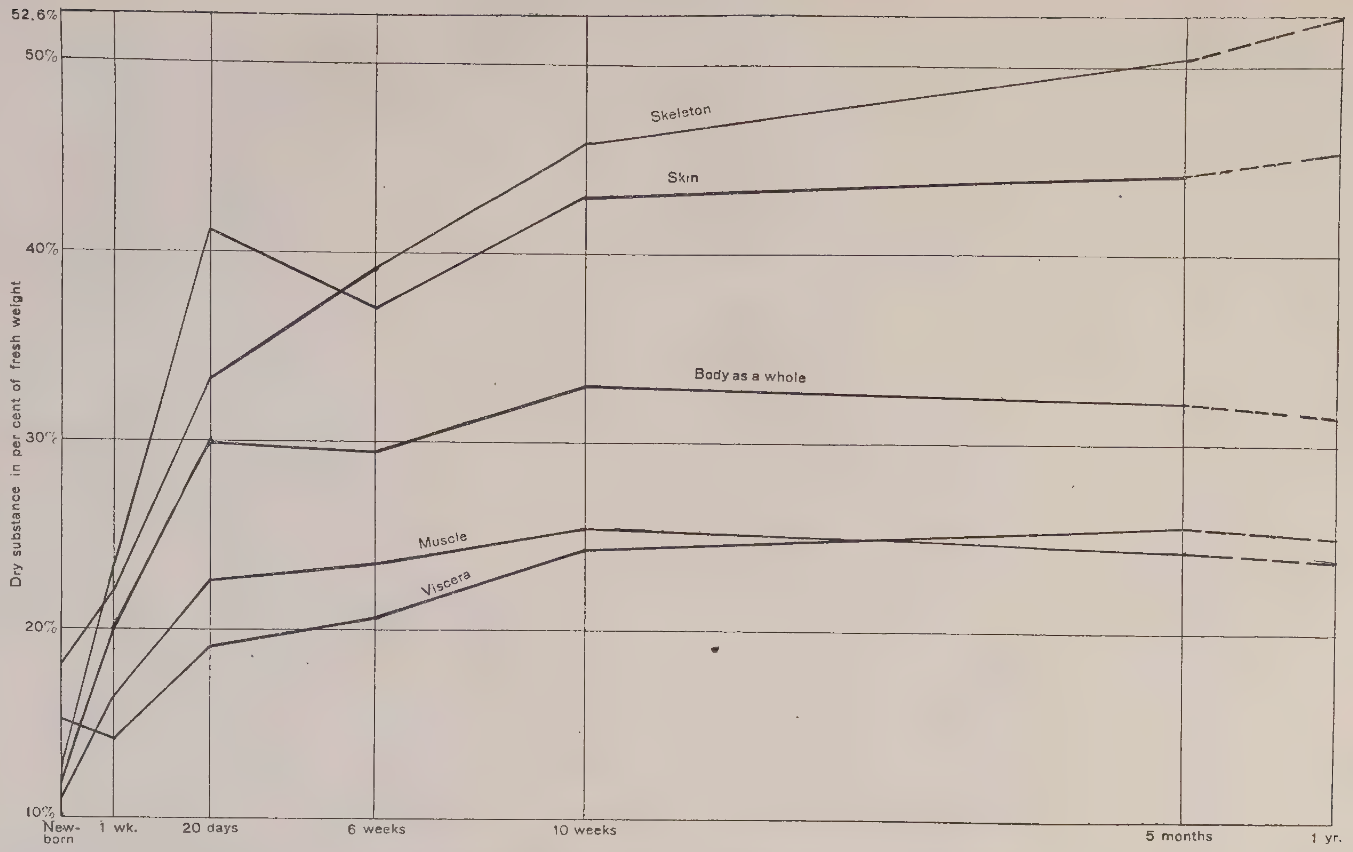

Fig. 1 The dry substance of the skin, skeleton, musculature, visceral group and entire body of the white rat in per cent of the fresh weight.

fat therein, the latter varying with the nutritional plane of the animal.

No exactly comparable data were found in the literature. Observations on individual organs are fairly abundant and these will be considered in their proper place.

The individual viscera

Central nervous system. This has been studied by Donaldson ('11) in a large series of rats. He found that, at birth, the brain contains 12.4 per cent of dry substance and that the dry substance increases, at first rapidly, then more slowly, to about 22 per cent in old rats. For the cord, he found 14.6 per cent at birth and 32 per cent in the old rats. My figures, for a much smaller series are similar in range, smaller and more variable. They are therefore not included in table 1. For the newborn brain, I find an average of 10.6 per cent, and for the oldest rats, 20.7 per cent of dry matter: for the cord, 10.1 and 26.6 per cent, respectively. For details concerning the dry substance and water content of the central nervous system of the rat, reference may be made to the various papers by Donaldson and his associates.

Eyeballs: table 1; figure 2. From an average of 7.4 per cent at birth, the dry substance of the eyeballs increases to about 20 per cent in the one year rats. Ohlmueller gives 11 per cent of dry matter in the eyeballs of a fifty-six day infant; Vierordt (Bischoff), 13 per cent in an adult. The difference between rat and human eyeballs seems excessive and no explanation for the difference can be given.

Heart: table 1; figure 3. At birth the dry substance of the heart averages 13.8 per cent; at twenty days, 18 per cent. The average daily increase appears much greater between the ages of seven and twenty days than between birth and seven days. In the older rats, the amount of dry substance increases to about 22.4 per cent.

The dry substance of the human heart increases from about 16.65 per cent at birth (Bischoff) to about 20 per cent in the adult, judging from several cases cited by Vierordt. According to these figures, the human heart has somewhat more dry substance at birth and somewhat less in the adult, than has the rat's heart.

Lungs: table 1; figure 3. The dry substance of the lungs increases from an average of 15.9 per cent at birth to 18.9 per cent at twenty days. The later stages have a slightly smaller percentage of dry substance. The decline in the two old rats is perhaps due to individual variation.

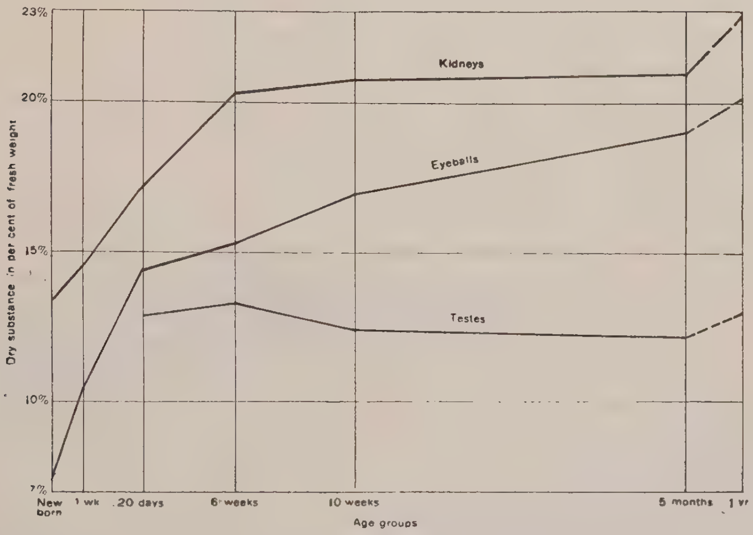

Fig. 2 Dry substance of the eyeballs, kidneys and testes in per cent of the fresh weight.

At fifty-six days the human lungs have 20.64 per cent of dry substance (Ohlmueller); in the adult, about 16 to 21 per cent (according to data cited by Vierordt).

Liver: table 1; figure 3. The dry substance of the liver increases from an average of 19.4 per cent at birth to 24.3 per cent at twenty days, thereafter very slowly to about 26 per cent in the old rats. The individual variation within the groups is not to be considered excessive, when the variable fat content of the liver is recalled. The percentage of dry substance in the liver is much higher than that of the other viscera studied.

The dry substance of the human liver is similar in amount to that found in the rat, according to data cited by Vierordt. At birth, there is about 19.45 per cent (Bischoff); at fifty-six days, 26.96 per cent (Ohlmueller); and for adults, about 23 to 32 per cent of dry substance. This is the only case where very close agreement in the amount of dry substance in the two species is found at birth, though it is unsafe to base comparison upon a single human specimen.

Spleen: table 1; figure 3. The dry substance of the spleen averages 14.3 per cent at seven days; 19.8 per cent at six weeks and 22.6 per cent in the old. This last figure is possibly due to individual variation. In three females of the six weeks lot, the spleen was about three times the normal size, without affecting the percentage of water to any marked degree.

The dry substance of the human spleen (according to data cited by Vierordt) is, at birth 21.55 per cent of the fresh weight; at fifty-six days 22.32 per cent; and in the adult 23.4 to 24.2 per cent. The increase in dry substance is less marked and the adult content somewhat greater than in the rat's spleen.

Testes: table 1; figure 2. The testes (without the epididymis) were first determined as separate organs in the twenty day lot. The record for the testes is remarkable on account of the fact that there is so little change in the content of dry material throughout the observations. This is interesting in view of their function. Observations on the ovary (not in table) indicate that it does show an increase in dry substance with age, which is perhaps due to an increase in fibrous tissue.

The human testes showed 16.11 per cent of dry substance in one case at fifty-six days 'Ohlmueller' and 14.15 per cent in one adult cited by Vierordt. This apparent loss would possibly not hold with more observations.

Comparing the foregoing data, it appears that the kidneys and heart have about the same relative amount of dry substance in all the age groups. The liver always has considerably more than either of these organs. The amount of dry substance depends upon the architecture of the organ and the amount of fat and blood present. Possibly the amount of fat present explains the greater percentage of dry substance in the liver.

The 'remainder'. The 'remainder' shows a marked decrease in relative fresh weight during the first week, decreasing more slowly thereafter in all stages observed. Jackson and Lowrey have attributed this early decrease to disappearance of excessive liquids. That this is the case is shown by the fact that the dry substance of the 'remainder' averages 4.76 per cent at birth and 27.2 per cent at one week. There is a great deal of variation in the dry content of the remainder in later stages, but there is from 35 per cent to 40 per cent of dry substance. It is significant that the remainder shows less dry substance at six weeks than at twenty days, and that there is a loss in dry content in the one year rats. This probably indicates a lessened amount of fat in these animals.

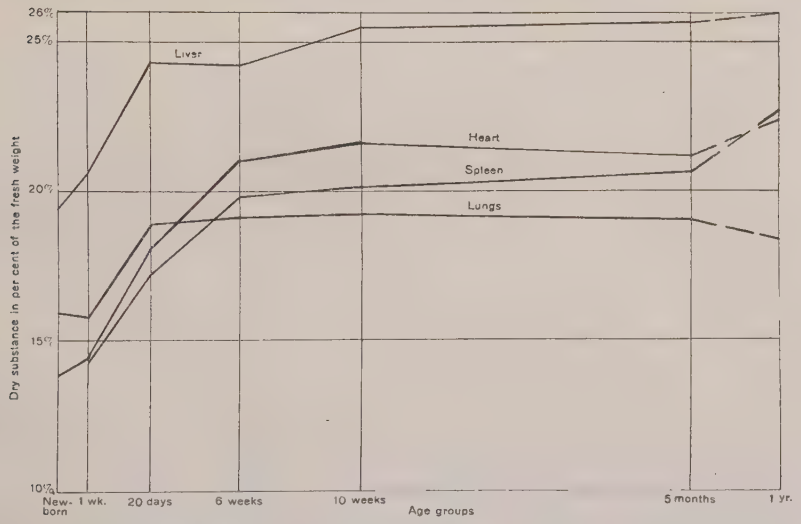

Fig. 3 Dry substance of heart, lungs, spleen and liver in per cent of the fresh weight.

THE DRY SUBSTANCE OF THE BODY

As stated above, the figures for the dry substance of the body have been secured by addition of the dry weights of the various parts. The discussion of the body as a whole has therefore been reserved to the last.

Inspection of the average fresh body weights in table 1 will show that the increases in weight from group to group are not uniform. In order to make comparison more easy, table 2 is inserted. This shows the increase in fresh body weight in grams, in per cent and in average daily per cent, as well as the per cent of increase for the dry body for each corresponding age period.

It will be seen from this that the daily percentage increase grows less and less, and that the periodic increase varies.

At birth the dry substance forms only about 12 per cent of the net body weight. During the succeeding twenty days, the dry substance increases at the rate of nearly 1 per cent a day, so that, at twenty days, nearly 30 per cent of dry substance is found. This increases to 33 per cent at ten weeks which represents practially the adult condition. The loss in the last two groups is probably due to absorption of fat, which seems to have already begun in the rats at five months and one year.

TABLE 2

The increase in the fresh body weight of the rats during the period of observation

PERIOD	WEIGHT AT START (a)	WEIGHT AT END (b)	INCREASE OF BODY WEIGHT			CORRESPONDING INCREASE OF DRY BODY TOTAL
			(b–a)	$\frac{(b-a) \times 100}{a}$	Average increase daily	
			grams	*per cent*	*per cent*	*per cent*
Birth to 1 week	4.22	9.05	4.86	114	16.0	260
1 week to 20 days	9.05	24.5	15.4	170	8.5	420
20 days to 6 weeks	24.5	61.3	36.8	150	7.0	137
6 to 10 weeks	61.3	126.7	65.4	106	3.8	147
10 weeks to 5 months	126.7	182.4	55.7	44	0.55	42
5 months to 1 year	182.4	267.5	85.1	47	0.24	39

Comparing the figures for the dry body (last column in table 2) with those for the fresh body, it appears that the dry body weight increases more than twice as much in the first period (260 per cent) and over three times as much in the second period (420 per cent). After that time the increase for both in each period is almost the same. That is because after ten weeks the percentage of dry substance in the body is nearly constant.

By collecting data from various sources, a fairly complete record of the growth of the dry substance in the human may be secured. These data are given in table 3. The figures for the fetal stages, two of the newborn and the thirteen day infant are from Fehling ('77); those for six of the newborn and the fifteen months infant from Camerer, Jr. ('02); for the fifty-six day infant from Ohlmueller ('82); for the adults, from Vierordt ('06).

The only observations in this table which are directly comparable with those of the rat are those after birth. It is worthy of note, however, that the amount of dry substance in the rat at birth is about the same as that of the human at approximately the beginning of the sixth month of intrauterine life. This perhaps corresponds to the immature condition of the rat at birth.

TABLE 3

The dry substance of the human body (prenatal and postnatal) in per cent of the fresh weight

AGE	NUMBER AND SEX	AVERAGE PER CENT DRY SUBSTANCE	AGE	NUMBER AND SEX	AVERAGE PER CENT DRY SUBSTANCE
Embryo of 6 weeks[1]	1 m.	2.46	8th month	1 f.	17.1
4th month..........	2 f.	8.62	newborn...	8 f.	27.55
5th month (1st half)	2 f.	8.05	13 days[2]	1 f.	26.1
5th month (2d half)	3 m.–2 f.	10.07	56 days..........	1–	40.0[3]
6th month..........	1 m.–2 f.	13.54	15 months........	1–	44.0
7th month..........	2 m.–2 f.	16.30	adult............	3–	35.9 (34.3–41.5)

[1] After E. Bischoff.

[2] Premature birth; atrophic.

[3] Fat-free equals 24 per cent of dry substance.

The amount of dry substance in the newborn human nearly equals that found in the twenty day old rat. It would seem that the adult human has relatively more dry substance than has the adult rat.

For other species the data are more scanty. Fehling ('77) gives a table showing the percentage of water in rabbit embryos. This shows that in the period between twelve and fifteen days of intrauterine life the embryos (average of 2) have 8.5 per cent of dry substance; at birth (2), 22.25 per cent; fourteen days post partum (2) 29.65 per cent. Inaba ('11) gives for an adult (?) rabbit 33.01 per cent of dry substance.

For the dog, Thomas ('11) gives observations on six puppies of the same litter killed at intervals. At birth (2 individuals) there was 19.9 per cent of dry substance; at nine days, 26.3 per cent; at twenty-one days, 31.6 per cent; at fifty-nine days, 29.5 per cent; at 106 days, 31.5 per cent. Observations on five kittens showed 19.21 per cent of dry substance at birth (2 individuals): 20.33 per cent at nine days; 26.19 per cent at 22 days; 33.35 per cent at 103 days.

Inaba gives some data on the water content of different animals. Those cases in which more than one determination were made are as follows: newborn white mouse, 16.0 per cent; young white mice (average of 3) 30.89 per cent of dry substance; guinea-pig embryo, 15.31 per cent, and newborn, 29.76 per cent.

Lawes and Gilbert ('59) found 34.9 per cent of dry substance in a fat calf; 43.9 per cent in a medium fat, and 51.6 per cent in a fat ox. A fat lamb had 47.1 per cent dry substance; lean sheep, 38.6 per cent; medium fat old sheep, 44.4 per cent; fat, 54.4 per cent and a very fat sheep, 63.8 per cent. A lean hog had 41.9 per cent and a fat hog 56.9 per cent of dry substance. The foregoing percentages are based on the fat-containing weights. When the fat was removed, the fat calf had 23.3 per cent, the medium fat ox 29.5 per cent, and the fat ox 29.5 per cent of dry substance. The fat lamb had 17.5 per cent, the lean sheep 21.9 per cent, medium fat old sheep 23.7 per cent, fat sheep 23.9 per cent and the very fat 25.6 per cent of dry substance. The lean hog had 22.8 per cent and the fat 23.3 per cent of dry substance.

Bezold ('57) made an extensive investigation of the water content, organic material and inorganic material in the bodies of a large number of animals, both vertebrates and invertebrates. He was the first to show that with advancing age the amount of water decreases and the amount of dry substance increases. Certain other researches existed at that time, in particular those of Baudrimont and St. Ange on the frog and of Prevost and Morin on the chick, but, while the importance of water in growth was recognized (cf. Davenport), no such sweeping conclusion as this had been possible. Bezold also pointed out that the amount of dry substance shows the greatest increase in the earlier stages, and that adults of different ages do not show much change. His use of the term 'dry material' is the same as in this paper, that is, it means that material which is left after dessication in an oven.

For white mice he found that eight embryos about one-half inch long contained 12.84 per cent of dry substance; two newborn, an average of 17.21 per cent; eight days old, 23.22 per cent and two old females showed an average of 28.72 per cent of dry substance. One young adult bat contained 31.33 per cent and one old adult 32.47 per cent of dry substance.

Bezold also gives numerous data for various birds, reptiles, amphibia, fishes and invertebrates. For these, the original paper should be consulted.

It appears that at birth, when there is not much fat present, judging by the visible amount, the rat has the smallest amount of dry substance and the greatest amount of water. The smaller animals, rat and mouse, have a relatively smaller amount of dry substance at birth than the larger animals, human, guinea-pig and dog. But the mouse has more dry substance than has the rat, and almost as much as the newborn dog. Those animals which double their weight in a short time after birth: rat (seven days), dog (nine days), rabbit (seven days) and the mouse (seven days ?) —show much less dry substance at birth than those taking a longer time: guinea-pig (twenty days) and human (180 days). The presence of a small amount of dry substance and a large proportion of water usually goes with a more vigorous and rapid growth.

THE RELATIVE GROWTH OF THE DRY SYSTEMS

In a recent paper, Jackson and Lowrey have shown the relative growth of the systems of the fresh body of the rat, and it will be of interest to compare the corresponding relative growth of the systems of the dry body. Table 4 contains the data from which figure 4 has been constructed.

The dry skin increases from an average of 21.2 per cent of the dry body at birth until at twenty days it forms 28.3 per cent of the dry body weight. At six weeks, the skin forms 24 per cent of the dry body, the further decrease in relative weight being slight.

TABLE 4

Percentage weight of skin, skeleton, muscle, viscera and remainder in the dry body

	NEWBORN	ONE WEEK	TWENTY DAYS	SIX WEEKS	TEN WEEKS	FIVE MONTHS	ONE YEAR
Number of observations	7	10[1]	9	10	7[1]	10	2
average dry body weight, grams	0.494	1.83	7.32	17.3	42.4	60.6	84.3
skin, per cent	21.2	27.9	28.3	24.0	23.3	23.4	22.9
	(20.0–22.6)	(24.8–31.4)	(25.9–32.6)	(22.2–25.7)	(21.9–25.0)	(19.0–26.2)	(22.1–23.7)
skeleton, per cent	24.3	20.1	18.7	19.8	16.3	17.1	17.5
	(21.3–27.2)	(17.8–22.4)	(17.4–23.3)	(17.8–24.7)	(13.9–17.6)	(13.7–20.0)	(17.1–18.0)
muscle, per cent	23.8	18.2	19.6	26.0	30.0	31.7	35.3
	(21.9–27.3)	(16.5–19.9)	(14.8–21.6)	(21.2–29.9)	(27.1–33.4)	(28.5–37.4)	(34.0–36.5)
viscera, per cent	22.5	13.9	13.0	14.6	12.1	11.8	9.4
	(20.6–27.0)	(10.7–16.3)	(10.4–15.6)	(13.0–16.5)	(11.1–13.1)	(8.9–13.6)	(9.3– 9.6)
remainder per cent	8.1	19.9	20.4	15.6	18.3	16.0	14.9
	(6.5–10.3)	(13.7–23.1)	(14.9–23.0)	(13.0–21.1)	(13.9–23.7)	(10.7–21.8)	(14.1–15.6)

[1] Skeleton and muscle not separately determined in one case.

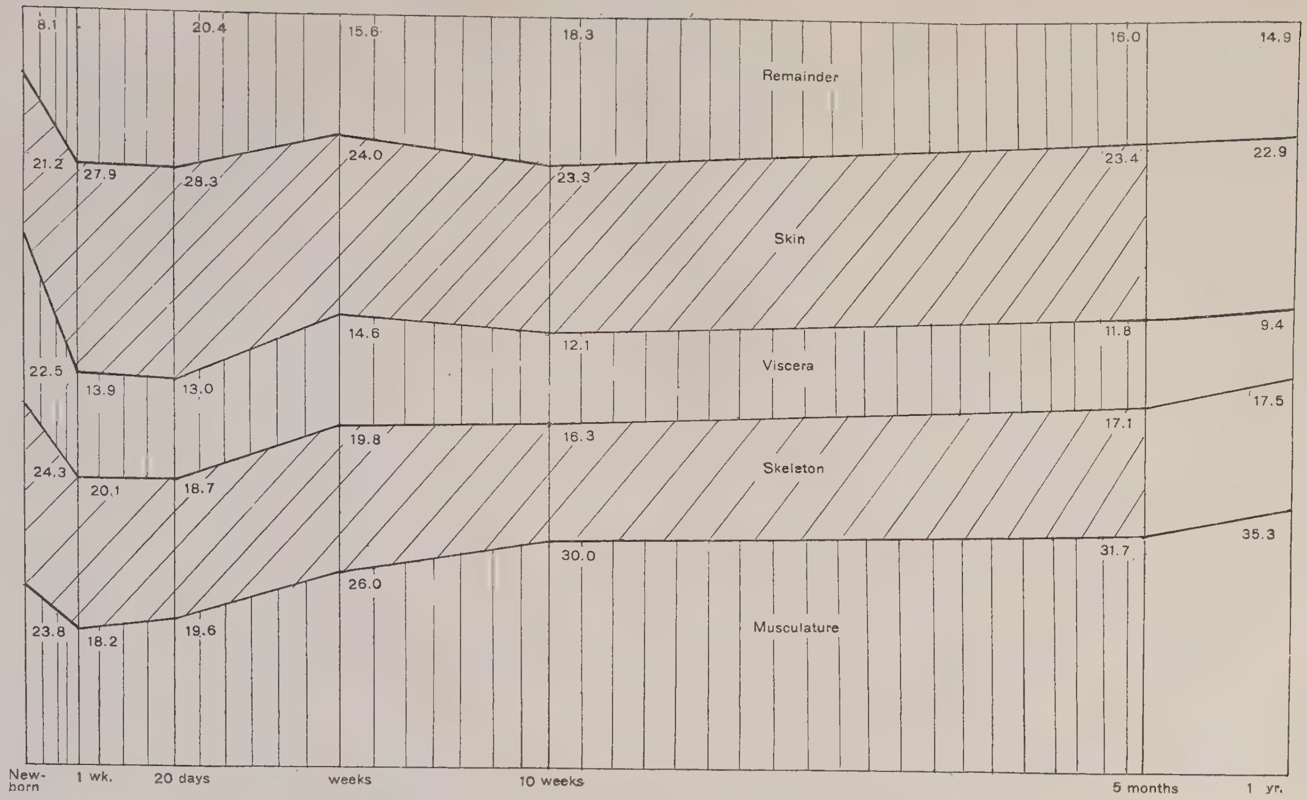

Fig. 4 Change in the percentage weight of the various systems of the dry body. The vertical width of each strip is proportional to the percentage weight of the corresponding system. The average percentage weight is indicated for every system at each of the ages. In the ruled portion, the horizontal distance is drawn to scale, proportional to the age. Beyond five months the horizontal distance is not in proportion to the age.

The fresh skin has its maximum relative weight of 25.88 per cent at seven days, decreasing thereafter in all stages to 17.95 per cent at one year. The dry skin is therefore always larger in relation to the dry weight than is the fresh skin in relation to the fresh body weight.

E. Voit found, in six dogs of varying size and nutritive conditions, that the dry skin formed from 11 to 27 per cent of the dry body weight. Figured on a fat-free basis, the skin formed 11 to 26 per cent and, reckoned on a fat-free and hair-free basis, 6 to 12 per cent of the dry body weight.

The dry skeleton forms 24.3 per cent of the dry body weight at birth; 18.7 per cent at twenty days; 19.8 per cent at six weeks and 17.5 per cent in the one year rats. The variations noted are probably due to the small number of observations.

The fresh skeleton reaches a maximum of 18.47 per cent at one week and thereafter decreases in relative weight, forming only about 10.9 per cent of the body weight in the one year rats. In each group the dry skeleton is relatively larger than the fresh.

For the dogs mentioned above, Voit found that the dry skeleton formed from 15 to 41 per cent of the dry body weights; 25 to 48 per cent figured on a fat-free basis and 28 to 52 per cent on a fat free, hair-free basis.

The dry musculature undergoes a decrease in relative weight from 23.8 per cent of the dry body at birth to 18.2 per cent at one week, then increases, at first rapidly, then more slowly, to 35.3 per cent at one year.

The fresh muscle shows a corresponding course, forming 24.37 per cent of the body weight at birth; 22.82 per cent at one week and 45.4 per cent at one year. The fresh muscle is at all stages relatively larger than the dry and the difference increases at each stage after birth up to the age of ten weeks. The smaller percentage for the dry muscle corresponds to the relatively small proportion of dry substance in the fresh muscle (fig. 1).

For the dogs, Voit found that the dry muscle forms from 25 to 35 per cent of the dry body weight; on a fat-free basis, 24 to 41 per cent; hair-and fat-free, 26 to 46 per cent. He also found that the fresh muscle is always relatively larger than is the dry.

The dry viscera form 22.5 per cent of the dry body weight at birth; 13.9 per cent at one week; 14.6 per cent at six weeks; decreasing thereafter to 9.4 per cent in the one year rats.

The fresh viscera increase slightly in relative weight for the first twenty days and at this time form 21.3 per cent of the body weight (Jackson and Lowrey) as compared with 13.0 per cent for the dry organs. Except in the newborn group, the fresh viscera are always relatively heavier than the dry.

Voit found that the viscera (excluding the heart) formed 12 to 16 per cent of the dry body weight in the dogs; 9 to 15 per cent figured on a fat-free basis; 10 to 16 per cent on a hair-and fat-free basis. He also found that the fresh viscera always are relatively heavier than the dry.

The dry 'remainder' forms only about 8 per cent of the dry body weight at birth and increases to about 20 per cent at one week. This is in marked contrast to the decrease in the relative weight of the fresh remainder from 20.56 per cent at birth to 13.68 per cent at one week (Jackson and Lowrey). Excepting at birth, the dry remainder is always relatively larger than the fresh, due to its large amount of fat giving a high content of dry substance.

CONCLUSIONS

The more important conclusions may be summarized as follows:

1. The dry substance of the skin increases from about 12.3 per cent of its weight at birth to about 41.1 per cent at twenty days, increasing slightly in the older stages. In comparison with the fresh percentage weight, the dry percentage weight (of the dry body) is always greater and increases for a longer time.

2. The dry substance of the skeleton increases from about 18.1 percent at birth to about 33.3 per cent at twenty days, and to 52.6 per cent at one year. The increase in dry substance is due largely to increase in fat content. In comparison with the fresh percentage weight, the dry percentage weight (of the dry body) is always greater, and has its maximum at birth.

3. The dry substance of the musculature increases from about 10.7 per cent at birth to about 22.6 per cent at twenty days and

25.2 per cent at ten weeks, decreasing slightly thereafter. The fresh muscle shows a marked relative growth, associated with a relatively small amount of dry substance. The percentage weight of the dry muscle (compared with the dry body) is always less than that of the fresh.

4. The dry substance of the visceral group increases from about 15.2 per cent at birth to about 19.1 per cent at twenty days and to a maximum of about 25.6 per cent at five months. The relative weight of the dry substance (compared with the dry body) is always less than that of the fresh viscera, except at birth.

5. The dry substance of the eyeballs increases from about 7.4 per cent at birth to 14.4 per cent at twenty days and 20.15 per cent at one year. The change is apparently much greater than in the human eyeballs.

6. The dry substance of the heart increases from about 13.8 per cent at birth to about 18.0 per cent at twenty days and to 22.4 per cent at one year.

7. The dry substance of the lungs increases from about 15.9 per cent at birth to 18.9 per cent at twenty days, this figure being fairly constant for the remaining later stages.

8. The dry substance of the liver increases from about 19.4 per cent at birth to 24.3 per cent at twenty days and to about 26 per cent at one year.

9. The dry substance of the spleen increases from about 14.3 per cent at seven days to 17.2 per cent at twenty days and to 22.6 per cent at one year.

10. The dry substance of the kidneys increases from about 13.3 per cent at birth to 17.2 per cent at twenty days and to 22.9 per cent at one year.

11. The testes have at all ages from twenty days onward about 13 per cent of dry substance.

12. The dry substance of the whole body increases from about 11.7 per cent at birth to 29.9 per cent at twenty days, and to a maximum of about 33.0 per cent at ten weeks, later decreasing

to about 31.5 per cent in the one year rats. In comparison with the fresh weight, the dry substance increases more than twice as fast during the first twenty days, the rate thereafter being more nearly equal. The percentage of dry substance in the body as a whole is greater than that of the viscera and musculature, but less than that of the skin and skeleton.

13. Individuals of the same age vary in the content of dry substance according to variations in the amount of fat present.

I am indebted to Professor Jackson for his many helpful suggestions and for reading the manuscript.

BIBLIOGRAPHY

Bezold, A. von 1857 Untersuchungen über die Vertheilung von Wasser, organische Materie und anorganischen Verbindungen im Thierreiche. Zeitschr. f. wissenschaftliche Zoologie, Bd. 8.

Camerer, Jr., W. 1902 Die chemische Zusammensetzung des neugebornen Menschen. Zeitschr. f. Biol., Bd. 43.

Davenport, C. B. 1908 Experimental morphology.

Donaldson, H. H. 1910 On the percentage of water in the brain and in the spinal cord of the albino rat. Jour. Comp. Neur., vol. 20; (see also papers by Donaldson in same journal, vol. 21, 1911, and in Anat. Rec., vol. 6, 1912).

Fehling, H. 1877 Beiträge zur Physiologie des placentaren Stoffverkehrs. Archiv f. Gynaekologie, Bd. 11.

Forster, J. 1873 Versuche über die Bedeutung der Aschenbestandtheile in der Nahrung. Ztschr. f. Biol. Bd. 9.

Inaba, Riotaro 1911 Ueber die Zusammensetzung des Tierkörpers. Archiv f. Anat. und Physiol., Physiologische Abteilung. H. 1 and 2.

Jackson, C. M. and Lowrey, L. G. 1912 On the relative growth of the component parts and systems of the albino rat. Anat. Rec., vol. 6.

Lawes and Gilbert 1859 Experimental inquiry into the composition of the animals fed and slaughtered as human food. Philos. Trans. Royal Soc. London, Part 2.

Ohlmüller, W. 1882 Die Abnahme der einzelnen Organe bei an Atrophie gestorbenen Kindern. Zeitschr. f. Biol., Bd. 18.

Petersen, P. 1871 Ueber die Schwankungen im Wasser, Fett- und Stickstoffgehalt des Fleisches. Zeitschr. f. Biol., Bd. 7.

Sedlmair, A. C. 1899 Ueber die Abnahme der Organe, insbesondere der Knochen, beim Hunger. Zeitschr. f. Biol., Bd. 37.

THOMAS, KARL 1911 Ueber die Zusammensetzung von Hund und Katze während der Verdoppelungsperioden des Geburtsgewichtes. Archiv. f. Anat. und Physiol., Physiologische Abteilung, H. 1 and 2.

VIERORDT, H. 1906 Anatomische, Physiologische und Physikalische Daten und Tabellen. 3 Aufl. Jena.

VINSON, A. E. 1904 Beiträge zur Methodik der Analyse ganzer Tierkörper. Inaug. Dissert. Göttingen.

VOIT, ERWIN 1905 (a) Welchen Schwankungen unterliegt das Verhältnis der Organgewichte zum Gesamtgewicht des Tieres? (b) Die Abnahme des Skeletts und der Weichteile bei Hunger. Zeitschr. f. Biol., Bd. 46.

WEISKE, H. 1895. Weitere Beiträge zur Frage über die Wirkung eines Futters mit sauren Eigenschaften auf den Organismus, insbesondere auf das Skelett. Zeitschr. f. Physiol. Chemie, Bd. 20.

CHELONIAN BRAIN-MEMBRANES, BRAIN-BLADDER, METAPORE AND METAPLEXUS[1]

J. P. MUNSON

NINE FIGURES

The brain of turtles is thought to have been first described in 1687, by Caldesi. Since then the following have made contributions of more or less value: Cuvier, 1809; C. G. Carus, '14; Tiedeman, '16; Bojanus, '19; Swan, '35; Grant, '42; Stannius, '56; Agassiz, '57; Owen, '66; Gegenbaur, '70: Stieda, '75; Herrick, '91; A. Meyer, '92; Sorensen, '94; Humphrey, '94; Gage, '95; Voeltzkow, 1903; Banchi, '03.

The literature will be considered when my completed results are published. The items contained in the present paper, and in the two or three on neuro-cytological subjects, that are to follow, have little in common with the results already published by the above authors. None of them have given any attention to speak of, first, to the minute surface details; second, to the cell structure.[2]

Contrary to opinions expressed by some, the chelonian brain is not too small to be studied macroscopically. It is easily removed from the skull. The method used by Gage, of decalcifying the skull, and sectioning the head entire, is not necessary; and for histological and cytological purposes, would seem impracticable.

THE BRAIN MEMBRANES

The dura is easily removed from the skull bones; especially on the dorsum, where it is most essential, if one wishes to study the epiphysis.

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[1] A contribution under Grant No. 154 of the Elizabeth Thompson Science Fund.

[2] *Material.* The following species of turtles have been examined in these studies: Chrysemys picta, Clemmys marmorata, Clemmys guttatus, Terrapena Carolina, and the snapping turtle.

If the brain, after removal be preserved for several weeks in Erlicki's solution:

Bichromate potash	2.5	parts
Sulphate of cu	1	part
Water	100	parts

the membranes are excellently preserved. They do not shrink; and they are tough, allowing necessary manipulation.

The dura is a thick and tough membrane, apparently serving as the periosteum of the skull. It has an outer and an inner smooth surface, consisting of closely packed parallel connective tissue fibers. There is no endothelial lining between it and the arachnoid. The central portion of the dura consists of less closely packed, parallel fibers; and it contains numerous lacunae, which give the appearance, in cross-section, of a tendency to split into two membranes, an outer and an inner (fig. 5, *d*).

The dura peels off readily from the arachnoid beneath; and, when removed, the brain presents a smooth appearance, as if there were no connecting trabeculae between these two outer membranes (fig. 5, *s*).

The arachnoid membrane, when preserved as indicated above, can also be removed, as it is very loosely applied over most of the surface (fig. 5, *a*). It peels off as a comparatively thick, tough membrane. The entire capillary system external to the brain is then revealed (figs. 1, 4, *c*).

A few thin connective tissue strands connect the arachnoid with the pia, which closely invests the substance of the cord and brain (fig. 9, *t*).

These trabeculae are most abundant over the optic lobes. Hence their woolly appearance, after removal of the arachnoid (fig. 4, *t*).

The capillaries never come off with the arachnoid, but remain entirely undisturbed. Even in uninjected specimens, the capillary system covering the entire brain can be seen in all its details (fig. 1, 4).

The pia is closely applied to the brain substance; but with this method of preservation, it, too, can be peeled off and examined in toto. On its inner surface (fig. 9, *u*) it consists of parallel connective tissue fibers, arranged transversely in the form of a membrane.

Scattered over the inner surface of the pia, peculiar cells are sometimes found, which do not appear to be organically connected with the membrane proper. They are distinctly cyanophilous and they multiply by budding.

In sections, the outer layer of the pia is more open, being made of fine fibers forming a close areolar tissue, continuous with the outer layer of the capillaries (fig. 6, *u*). This outer layer of the pia, can be removed in patches together with the capillaries, but it cannot be called a membrane. Under the microscope, it proves to be a very loose network of connective tissue fibers. The latter have a wavy appearance, like the cell outlines in endothelium; and may easily be mistaken for such a membrane, in some places.

The outer layer of the pia resembles the inner layer of the arachnoid so closely, that one is strongly tempted to infer that the pia and arachnoid are originally one membrane, with two compact surfaces, and a loose areolar tissue between, in which the capillaries develop (fig. 9, *v*). Later the original membrane splits; so that the outer lamina becomes practically separated from the inner (fig. 9, *a*, *u*), with which the capillaries are more intimately associated, because of their extension into the brain substance (fig. 5, *g*).

The space between the pia and the arachnoid is, therefore, not a closed serous cavity, lined with endothelium; but, rather, a large open split, between the inner and the outer fibrous surfaces.

Neither in the subarachnoid nor in the subdural space is there any indication of a serous membrane that can account for the arachnoid fluid, as Huxley maintained in regard to the human brain and cord. This becomes of importance in the interpretation of the choroidplexus and the metatelus.

METAPORE

The metapore (fig. 1, *p*) seems to be an object of contention among investigators. It is generally assumed to be an opening through the dorsal wall of the neural tube, communicating with the subarachnoid space. Strangely enough, neither Humphrey

(16) nor Gage (17) found any positive evidence of it in turtles, and have only conjectures to offer, excellent as their work is in all respects. Their method of study, solely by means of sections, was not well adapted to the subject. It is an interesting problem readily solved by the simple method which I have employed.[3]

The substance of the brain has been developed between two membranes—the original ectodermal epithelium of the neural tube, the ependyma, on the inside; and the pia outside (fig. 5, *e*, *r*). In the region of the hypophysis, on the ventral side, and in the roof of the diencephalon, these two membranes remain intimately associated, there being no nerve matter developed between them. As I shall show in my completed work, both the epiphysis and paraphysis, including the dorsal sac, of the diencephalon, consist of these two membranes, as do the epiplexus, the paraplexus and the plexuses of the lateral ventricles.

The roof of the metencephalon is similarly composed of these two layers (fig. 6) with the single exception of an oval area at the posterior angle of the fourth ventricle, just in front of the dorsal fissure of the cord, where this opens up to form the fourth ventricle (fig. 1, *p*). Here the metacoel is covered by one membrane only, the metatelus, an extension of the endyma cells lining the ventricles and the central canal (fig. 5, *e*, *b*).

This oval opening is the metapore (fig. 1, 3, 4, *p*). But there is no direct communication through it, between the central neural canal, ventricle, and the subarachnoid space.

BRAIN-BLADDER

The brain-bladder is a closed sac (fig. 2, *b*), projecting through the metapore in the pia. It is a single layer of cells derived from and continuous with the endyma lining the brain cavities (fig. 5, *b*). The metapore, consequently, corresponds to the duct leading from the neural canal into the brain-bladder (fig. 4, *p*, *b*).

With the exception of this connection with the ventricles and neural canal, the brain-bladder is a closed sac, similar to a real serous sac, which, as is well known, with one exception—the peritoneum of females—is always a closed sac.

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[3] Mrs. Gage (20) says: "Wilder (21) has demonstrated that in the adult man and certain apes, in the caudal region of the metaplexus, there is a lack of continuity

The brain-bladder seems in fact to be the only serous sac connected with the brain, unless the epiphysis, dorsal sac, and the hypophysis with its corresponding sac, saccus vasculosus of teleosts, be so regarded. These, however, are accompanied by the pia, and cannot be said to lie in the arachnoid space.

The brain-bladder lies in the subarachnoid space without adhering to the walls of that cavity as is usual with serous membranes (fig. 5, *b*).

The arachnoid membrane is attached firmly to the pia along a line corresponding to the superficial origin of the cranial nerves, (figs. 2, 5). Above this line it forms a loose bag in which the brain-bladder lies (fig. 5, *a*). Even the cranial cavity itself is enlarged in this region, as if to accommodate the brain-bladder when inflated.

Removing the arachnoid over the anterior part of the cord, and the medulla, the brain-bladder appears as an oval membrane slightly lighter in color than the surrounding tissues (fig. 2, *b*). It extends back over the cord, out on both sides and forward over the metaplexus.

Occasionally it is partly inflated but usually collapsed. The wide space between the arachnoid and the capillaries on the pia affords ample room for it to expand when inflated. When not inflated, it lies flat, not wrinkled or folded. Being so delicate, one is apt to mistake it for a piece of the arachnoid or some other membrane.

If a hypodermic syringe, filled with water (the entire brain being under water), be inserted through the side of the medulla, below the bladder, and water be thus injected into the ventricle, the brain-bladder becomes inflated through the metapore. It then appears as a spherical or oval body standing up well from the brain like a toy balloon or perhaps rather say, a good sized soap

in the endyma and pia, thus placing the cavities of the brain in communication with subarachnoid spaces?'' She says of diemyctylus, that ''the conclusion that a true metapore exists is unavoidable.'' There is of course a metapore in the pia but it does not lead directly into the subarachnoid space. What she calls 'endolymphatic sac' in figure 34 is very probably the brain-bladder.

bubble (fig. 4, *b*). It has the glittering appearance of a soap bubble. It is inelastic and does not collapse after inflation.

I have inflated this brain-bladder through the epiphysis, in the perfectly fresh brain. The removal of the arachnoid, so necessary to get a good view of it, is more difficult in the fresh brain. But if the arachnoid is only ruptured, the bladder is sometimes forced through the rupture when inflated in the fresh state.

If pricked with a needle after inflation, a fine stream issues; in some instances, carrying halfway across the table. It is much more easily studied when preserved as directed. Both its transparency and toughness is preserved; and further staining and preparation for the microscope, is easy

There are absolutely no pores in this bladder, leading into the subarachnoid space. That is very evident when it is inflated. If such a pore is what is meant by metapore, the answer must be, there is none.[4] Neither are there any indications of stomata. The pore is only in the pia (fig. 4, *p*).

The appearance of this brain-bladder is not due to the pressure of the injected fluid. Not only can it be seen in the arachnoid space, but it can be removed entire by means of fine scissors. This may be done either before or after inflation. In the latter case, it retains its expanded shape on the slide, where it can be studied microscopically. It is composed of a single layer of very flat hexagonal cells.

The metapore of the pia forms an oval, with the pia forming a thickened rim around the pore (fig. 1, *p*).

In preserved material, the metaplexus can be removed and with it the brain-bladder (fig. 3, *b*).

If the brain is first stained in toto in hematoxylin, before inflation of the bladder, fine permanent preparations can be made.

When removed with the plexus, the thickened rim of the metapore comes away with the brain-bladder (fig. 3, *p*).

The latter thus retains its connection with the metaplexus by a narrow, tough connective tissue band.

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[4] The foramen of Magendie is a similar object in the human brain, defined as "an interval in the piamater that roofs the fourth venticle of the brain, affording communication between the subarachnoid space and the ventricular cavities."

In removing the metaplexus, and the brain-bladder, in this way, the pia tears most readily along the line which extends obliquely from the line of attachment of the arachnoid to the anterior border of the metapore (fig. 1, *m*). Hence a part of the roof of the fourth ventricle remains after the removal of the plexus and the bladder. There appears to be a thickened band of connective tissue along this line, which joins the thickened border around the metapore.

The brain-bladder remains inflated after removal (fig. 3). If it be ruptured and spread out on the slide, it cannot be made to lie flat. To get a good view of its cell structure, it must be torn radically. Stained on the slide with hematoxylin, mounted in glycerine or dehydrated, cleared and mounted in balsam, its cell outlines are very clear, when the hardening has been done by means of Erlicki's fluid. Hermann's and Flemming's fluids give poor results, but are better for some purposes.

The cells of the brain-bladder have the outlines of endothelial cells of the serous membranes with straight edges (fig. 8). The cytoplasm is remarkably clear and free from stainable granules. Indeed no other part of the brain shows cells like these; though sections show very distinctly that they are continuous with the endyma cells lining the ventricle and central canal (fig 5, *b*, *e*).

The entire brain-bladder consists of a single layer of flattened endyma cells. Gage (17) figures the corresponding part in birds (sparrow) as being covered with a layer of the dura. A similar mistake accounts for the failure of previous observers to understand it, as the thing has evidently not been properly studied.

METAPLEXUS

The metaplexus forms the roof of the fourth ventricle, anterior to the brain-bladder (fig. 1, *k*). It consists of endyma cells covered externally by the pia and capillary network. It is so folded that the pia and capillaries come to lie between the folds of the endyma epithelium (fig. 6).

Removed entire and viewed from below, the folds are seen to resemble a series of ruffles, converging to the central line, corresponding to the dorsal fissure of the cord (fig. 3, *f*); and, like it, composed of connective tissue (fig. 3, *j*). The effect could be imitated by a square, arranged in longitudinal, parallel folds; but compressed at one end, corresponding to the handle of a palm-leaf fan. As the folds are wavy, sections rarely show the typical conditions. It can best be understood when viewed as a whole from the underside.

There are good reasons for comparing this with the dorsal sac of the paraphysis, the brain-bladder being compared to the epiphysis. The band passing transversely between the brain-bladder and the metaplexus would correspond, in position, to the supra-commissure in the diencephalon. But unlike this, the band seems to be wholly connective tissue, belonging to the pia; and no real commissure of nerve fibers exists here. When this band is cut, the walls of the fourth ventricle separate, revealing the fissures and ridges in the floor of the ventricle, arising from the fiber tracts of the cord continued in the medulla (fig. 1, *k*).

GENERAL CONSIDERATIONS

There may possibly be some objectors to the term, brain-bladder, as here used. The term 'sac' is certainly overcharged as a name for brain structures. 'Dorsal sac' has been used by writers on the chelonian brain, following Humphrey, to designate the thin walled expansion of the roof of the diencephalon in front of the supra-commissure, and supposed to be associated with the paraphysis, but really the paraphysis itself. To Latinize the word 'sac' would not help matters. 'Tela' is used to designate the thin roof of the neural tube, and does not denote a sac necessarily.

From the morphological point of view, and possibly from the functional side, the name bladder seems appropriate, when its derivation is considered. It is also specific.

Some idea of the function of organs can be gained from their structure, and their relation to other parts. Why not in this case also?

The haemal tube is lined with serous membrane, which lessens friction, by the smoothness of opposing surfaces; and by the fluid produced, keeping them moist.

It is known, also, that the fluid secreted by such membranes have a phagocytic or toxic effect on foreign cells. There are many such cells in the brain of turtles.

From the arrangement of the capillaries, and their relation to the endyma cells, inside the plexus, it is suggested that lymph from the blood oozes through the endyma cells into the ventricles. The brain-bladder is admirably arranged to allow the pressure between the ventricular and the subarachnoid fluid to be equalized (fig. 7, fig. 5). It may also allow lymph to filter through from either space as the pressure becomes unequal.

The nuclei of the bladder cells certainly show that they are not idle; while no indications of solid deposits in the cytoplasm appear. The nuclei may produce substances, antibodies, which when passed out with the lymph, passing through the cytoplasm, has a phagocytic action like that of the serum from the body cavity.

As already stated, the brain-bladder is the only closed sac in the neural tube that can be directly compared to that lining the body cavity, or the synovial sacs between joints.

That it varies with the pressure of the fluids within the ventricles and the central canal is sufficiently demonstrated by its inflation through the epiphysis as well as through the hypophysis.

It would be strange if such an apparatus as the plexus, so admirably arranged for exposing as much surface as possible, like so many gills (fig. 3, *j*) or lungs, were of no physiological importance.

The brain bladder appears to be prominent even in the human brain in its earlier stages. It remains to be seen whether it is not fully as prominent in the developed brain. It may be obscured by the crowding of nerve elements; so that, with the methods of study employed, it has been overlooked; as it certainly has, in the adult turtle's brain. It is prominent in birds, though it has been misinterpreted; and has not received the attention it deserves. Such a thing must be seen entire, not merely in sections.

If the method of preserving, exposing, and inflating, described above, be adopted, any one can see the brain-bladder (fig. 4, *b*). He will doubtless feel amply repaid for his trouble. A good view of this thing will, perhaps, make it as difficult for him as for me, to believe that it can be a mere useless embryonic vestige.

At any rate, it is to be hoped that those engaged in similar studies, on more developed brains than those of reptiles, will give more attention to this than has hitherto been the case.

LITERATURE CITED

(1) Caldesi 1687 Osservazione anatomicho intorno alle Tartarughe. Fierenze.

(2) Cuvier 1809 Leçons d'anatomie, Leipzig.

(3) Carus, C. G. 1814 Darstellung des Nerven systems und Hirns. Leipzig. Second Ed., t. Paris, 1845.

(4) Tiedemann 1816 Anatomie und Bildungsgeschichte des Gehirns des Menschen. Nurnberg.

(5) Bojanus 1819 Anatomie testudinis Europaeae. Vilna.

(6) Swan 1835 Illustrations of the comparative anatomy of the nervous system. London.

(7) Grant 1842 Umrisse der vergleichenden Anatomie. Leipzig.

(8) Stannius 1856 Handbuch der Anatomie der Wirbelthiere. Berlin.

(9) Agassiz, L. 1857 Contributions to the natural history of the United States. Part II.

(10) Owen, R. 1866 On the anatomy of vertebrates. Vol. 1. Fishes and reptiles. London.

(11) Gegenbaur 1870-1874 Grundzüge der vergleichenden Anatomie. Leipzig.

(12) Stieda, L. 1875 Über den Bau des Centralen Nervensytems der Schildkröte. Zietsch. f. w. zool. Bd. 25.

(13) Herrick, C. L. 1891 Contributions to the comparative morphology of the nervous system. II. Topography and histology of the brain of certain reptiles. Jour. Comp. Neur., vol 1.

(14) Meyer, Ad. 1892 Über das Vorderhirn einiger Reptilien, Inaug. Dissert. Zeitsch. f. w. zool., Bd. 55.

(15) Sorenson, A. D. 1894 Comparative study of the epiphysis and roof of the diencephalon. Jour. Comp. Neur., vol. 4.

(16) Humphrey, O. D. 1894 On the brain of the snapping turtle, Chelydra serpentina. Jour. Comp. Neur., vol. 4.

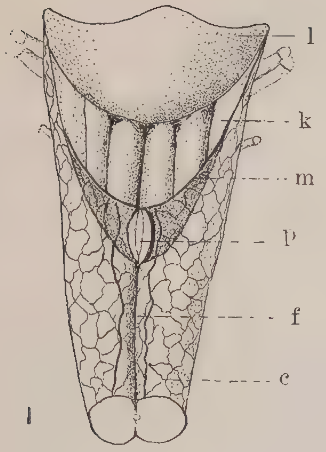
(17) Gage, Susanna P. 1895 Comparative morphology of the brain of the soft-shelled turtle, Amyda neutica, and the English sparrow, Passer domesticus. Proceedings Am. Micros. Soc., vol. 17.

(18) Voeltzkow, Alfred 1903 Beiträge zur Entwicklungsgeschichte der Reptilien. V. Epiphyse und Paraphyse bei Krokodilen und Schildkroten. Abh. Senckenberg. nat. Ges., Bd. 27.

(19) Edinger, Ludwig 1899 Untersuchungen über die vergliechende. Anatomie des Gehirnes. 4 Studien über das Zwischenhirn der Reptilien. Abh. Senckenb. nat. Ges. Frankurt a. M.

(20) Gage, Susanna P. 1893 The brain of Diemyctylus viridescens. Wilder Quarter-Century Book. Ithaca, N. Y.

(21) Wilder, B. G. 1884 The foramen of Magendie in man and the cat. New York Med. Jour., vol. 39.



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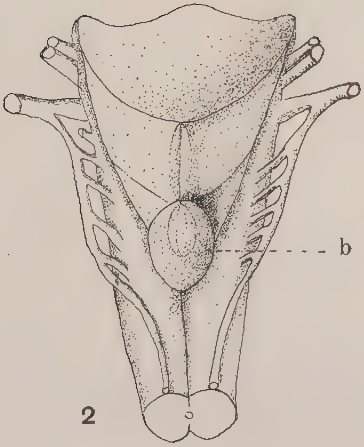

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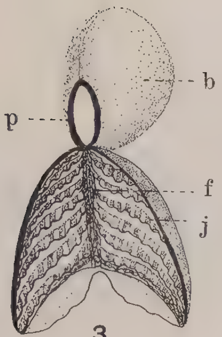

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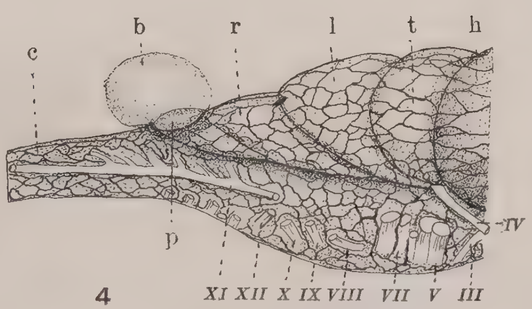


4

J. P. Munson

Fig. 1 Dorsal view of cord and metencephalon of the tortoise, Clemmys marmorata, with the dura and arachnoid removed, showing capillaries, *c*; dorsal fissure, *f*; metapore, *p*, after removal of the brain-bladder; the line along which the metatelus tears in removing the metaplexus, *m*; the sulci and ridges in the floor of the fourth ventricle, *k*; the cerebellum *l*.

Fig. 2 Dorsal view of metencephalon after removal of the two outer membranes, showing roof of fourth ventricle with the brain-bladder, *b*.

Fig. 3 Ventral view of the roof of fourth ventricle, showing the inflated brain-bladder, *b*; the thickened rim surrounding the metapore, *p*; the central septum corresponding to the dorsal fissure of the cord, *f*; the ruffle-like folds on under side of the metaplexus, *j*. Imagine this turned over and fitted onto figure 1 as the roof of the fourth ventricle.

Fig. 4. Side view of brain of clemmys, showing capillaries after removal of the dura and arachnoid, *c*; the cranial nerves III–XII; cerebral hemisphere, *h*; optic lobe, *t*; cerebellum, *l*; the roof of fourth ventricle, *r*, and the inflated brain-bladder, *b*, above the metapore, *p*.

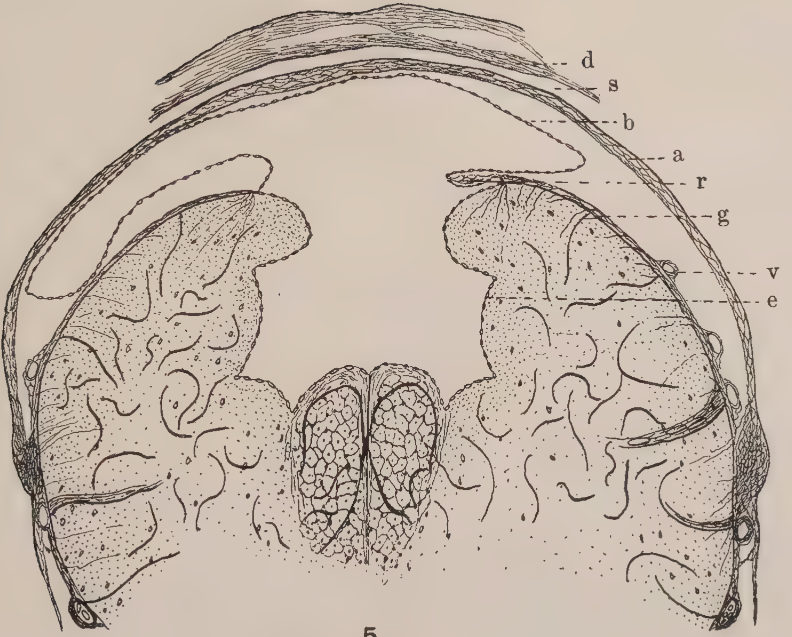
Fig. 5. Section through the metencephalon, in region of metapore, and showing section of brain-bladder, *b*, and its continuation with the endymal lining of ventricle, *e*; the subarachnoid space in which the brain-bladder lies and the connection of the arachnoid on either side with the pia; the connection of the capillaries, *v*, with the pia and their extension into the nerve substance, *c*; the subdural space, *s*, and the two smooth surfaces of the dura, *d*; the sulci and ridges seen in figure 1, *k*, also shown in section with the large ventral motor tracts on either side of the ventral fissure, showing the ventricle to be merely the expanded central canal.

Fig. 6 Transverse section of three folds of the metaplexus, showing the process of folding, *j*; the ependymal membrane, *e*; the pia, *u*; and the capillary network, *v*. Compare *e* and *g*, to note the difference in cells when compressed by lateral pressure in the plexus, or by lateral pull in the brain-bladder, *g*.

Fig. 7 Longitudinal section, showing substance of medulla below; and above it, the cavity of the fourth ventricle; covered above by cerebellum, showing Purkinge cells, *w*; metaplexus, *m*; brain-bladder, *b*; dorsal fissure, *i*; optic lobe, *o*.

Fig. 8 Surface of view of brain-bladder, with high magnifying powers, showing cell outlines, and their different kinds of nuclei.

Fig. 9 Brain membranes, showing tendency to split. Inner and outer layer of dura, *o*, *i*; subdural space; and below the two layers of connective tissue membranes, the outer or arachnoid, *a*; the inner pia, *u*; the connection between them by trabeculae, *t*, traversing the subarachnoid space, *x*; suggesting their original union into a single membrane; the more intimate connection of the capillary network with the deeper layer or pia, *v*; subpial surface of transverse connective tissue fibers, *u*.



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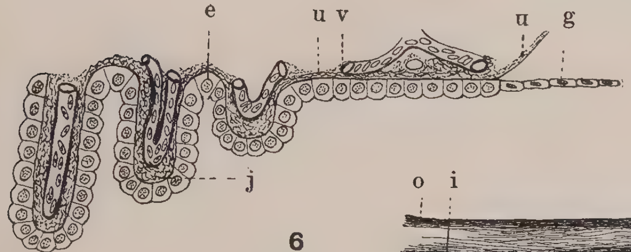

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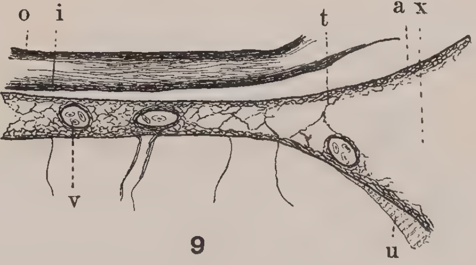

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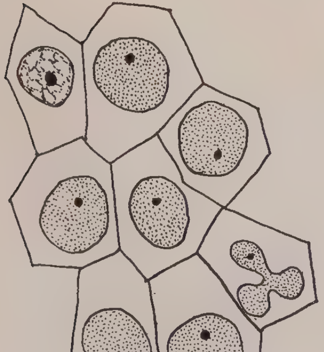

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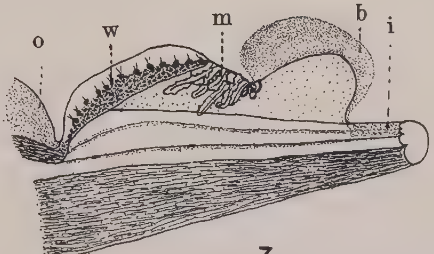

7

THE EFFECT OF SPAYING AND SEMI-SPAYING YOUNG ALBINO RATS (MUS NORVEGICUS ALBINUS) ON THE GROWTH IN BODY WEIGHT AND BODY LENGTH

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ELEVEN FIGURES

In connection with the study of the normal body growth of the albino rat, the attempt has been made to determine the modifications in body growth which follow the removal of the sex glands.

In the male albino rat, it was found (Stotsenburg '09) that (1) the growth graph of the castrates is similar to that for the normals; (2) castrates are as susceptible as normals to the incidental influences modifying growth; (3) castrates are as susceptible as normals to the forms of disease which hinder normal growth.

In a series of experiments covering a period of three years, observations on the effect on body growth caused by the removal of one or both ovaries from the female albino rat have also been made. In this study a total of 121 animals was used, those of each year constituting a separate series. The operated animals numbered 63 and the controls 58. The animals were weighed at regular intervals, and from the average weights by litters the growth graphs were plotted.

When complete spaying was practised the ovaries were removed in two operations; one when the animal was between sixteen and twenty-two days of age, the other a week later. The rats were always etherized and then secured in the prone position

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by tapes to a metal frame, the hair was clipped from the site of the incision, the latter being made through the tissues at the edge of the lumbar muscles, a little caudad to the last rib. The incision need not be more than 0.5 cm. in length and should not cause bleeding. A small blunt hook is inserted through the opening and the ovary brought out and cut from its attachments. The whole operation takes but a few minutes. The edges of the wound are brought together and covered with thin celloidin, and the animal is placed in warm cotton until consciousness has fully returned, when it is replaced in the nest. Preparatory to this last step it is a wise precaution to remove the mother from the nest and keep her apart for a short time so that the operated animal may have a chance to reacquire the nest odor, otherwise the mother may kill the young one when it is returned.

Beyond boiling the instruments, no aseptic precautions were ever taken, yet in no case have ill effects followed the operation as thus performed, the rat seeming not to be susceptible to infection through such wounds.

The rats were weighed at intervals ranging from a week to a month and the record kept for each individual, so long as the experiment continued. The experiment was usually brought to a close by the illness of some of the rats, indicated by loss in weight. In making up the tables on which the graphs are based, the entries are terminated before either the control or operated groups show any loss in weight. The data for all the series are given in tables 3 to 13. On these tables the several graphs are based.

TABLE 1

Albino rats. Data of litters used in the spayed series

	NUMBER OF LITTERS	NUMBER OF INDIVIDUALS		
		Spayed	Controls	Total
Series of 1909..........	6	16	15	31
Series of 1910..........	9	17	15	32
Series of 1911..........	2	5	5	10
	17	38	35	73

TABLE 2

Albino rats. Data of litters used in the semi-spayed series

	NUMBER OF LITTERS	NUMBER OF INDIVIDUALS		
		Semi-Spayed	Controls	Total
Series of 1910..........	7	13	12	25
Series of 1911..........	5	12	11	23
	12	25	23	48

TABLE 3

Spayed albino rats. Data from which the composite graph for 1909 was plotted. Average weights of 16 operated and 15 controls

AGE IN DAYS	OPERATED	CONTROLS	AGE IN DAYS	OPERATED	CONTROLS
	grams	*grams*		*grams*	*grams*
50	70	70	175	190	163
75	100	90	200	201	165
100	127	117	225	201	167
125	150	135	250	212	173
150	172	150	275	230	176

TABLE 4

Spayed albino rats. Data from which the composite graph for 1910 was plotted. Average weights of 17 operated and 15 controls

AGE IN DAYS	OPERATED	CONTROLS	AGE IN DAYS	OPERATED	CONTROLS
	grams	*grams*		*grams*	*grams*
50	49	50	150	133	114
75	76	72	175	139	118
100	102	93	200	146	125
125	122	108	225	150	128

TABLE 5

Spayed albino rats. Data from which the composite graph for 1909, 1910, 1911 was plotted. Average weights of 36 operated and 35 controls

AGE IN DAYS	OPERATED	CONTROLS	AGE IN DAYS	OPERATED	CONTROLS
	grams	*grams*		*grams*	*grams*
50	76	72	150	182	137
75	108	96	175	192	153
100	139	119	200	199	159
125	162	136	225	201	161

TABLE 6

Spayed albino rats. Data from which the minimum graph for 1911 was plotted. Average weights of 2 operated and 2 controls

AGE IN DAYS	OPERATED	CONTROLS	AGE IN DAYS	OPERATED	CONTROLS
	grams	*grams*		*grams*	*grams*
30	53	50	175	234	186
50	132	110	200	230	189
75	169	140	225	227	190
100	209	162	250	228	191
125	228	176	275	235	189
150	231	180	300	240	188

TABLE 7

Spayed albino rats. Data from which the maximum graph for 1911 was plotted. Average weights of 3 operated and 3 controls

AGE IN DAYS	OPERATED	CONTROLS	AGE IN DAYS	OPERATED	CONTROLS
	grams	*grams*		*grams*	*grams*
30	56	60	175	264	180
50	87	82	200	275	188
75	127	112	225	278	190
100	170	137	250	280	193
125	203	156	275	279	199
150	253	174	300	276	207

TABLE 8

Spayed albino rats. Data from which the composite graph for 1911 was plotted. Average weights of 5 operated and 5 controls

AGE IN DAYS	OPERATED	CONTROLS	AGE IN DAYS	OPERATED	CONTROLS
	grams	*grams*		*grams*	*grams*
50	109	96	200	252	188
75	148	126	225	252	190
100	189	149	250	254	192
125	215	166	275	257	194
150	242	177	300	258	197
175	249	183			

TABLE 9

Semi-spayed albino rats. Data from which the minimum graph for 1910 was plotted. Average weights of 1 operated and 2 controls

AGE IN DAYS	OPERATED	CONTROLS	AGE IN DAYS	OPERATED	CONTROLS
	grams	*grams*		*grams*	*grams*
50	60	54	150	111	114
75	75	72	175	118	116
100	88	89	200	123	118
125	100	105	225	127	116

TABLE 10

Semi-spayed albino rats. Data from which the maximum graph for 1910 was plotted. Average weights of 17 operated and 15 controls

AGE IN DAYS	OPERATED	CONTROLS	AGE IN DAYS	OPERATED	CONTROLS
	grams	*grams*		*grams*	*grams*
50	42	50	200	104	120
75	60	68	225	114	130
100	76	84	250	113	132
125	88	98	275	117	137
150	97	108	300	125	147
175	100	114			

TABLE 11

Semi-spayed albino rats. Data from which the composite graph for 1910 was plotted. Average weights of 13 operated and 12 controls

AGE IN DAYS	OPERATED	CONTROLS	AGE IN DAYS	OPERATED	CONTROLS
	grams	*grams*		*grams*	*grams*
50	50	49	200	119	116
75	69	70	225	125	121
100	85	82	250	125	130
125	98	96	275	135	137
150	108	106	300	137	149
175	116	112			

TABLE 12

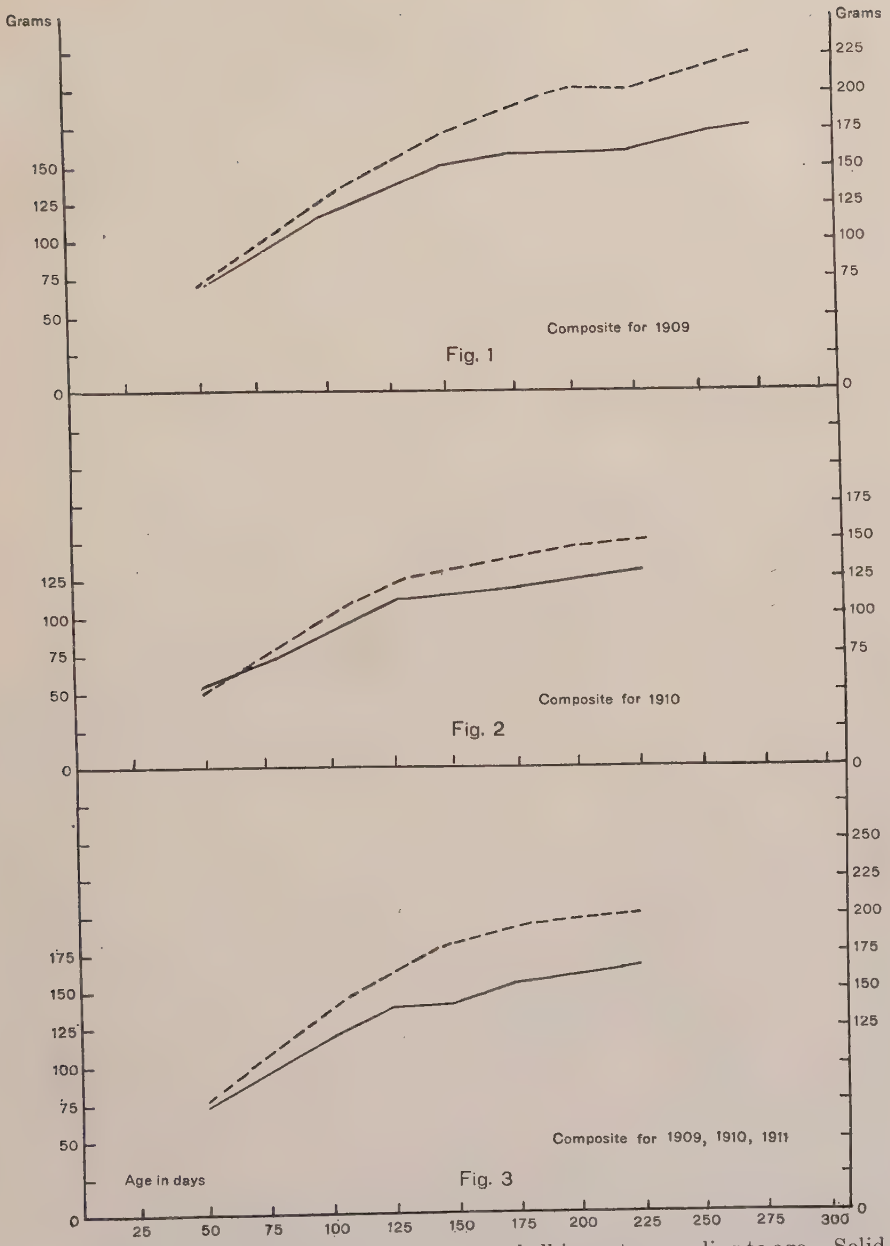
Semi-spayed albino rats. Data from which the composite graph for 1911 was plotted. Average weights of 12 operated and 11 controls

AGE IN DAYS	OPERATED	CONTROLS	AGE IN DAYS	OPERATED	CONTROLS
	grams	*grams*		*grams*	*grams*
50	57	59	200	154	158
75	88	89	225	158	162
100	116	119	250	162	164
125	130	134	275	165	167
150	144	150	300	160	160
175	149	154			

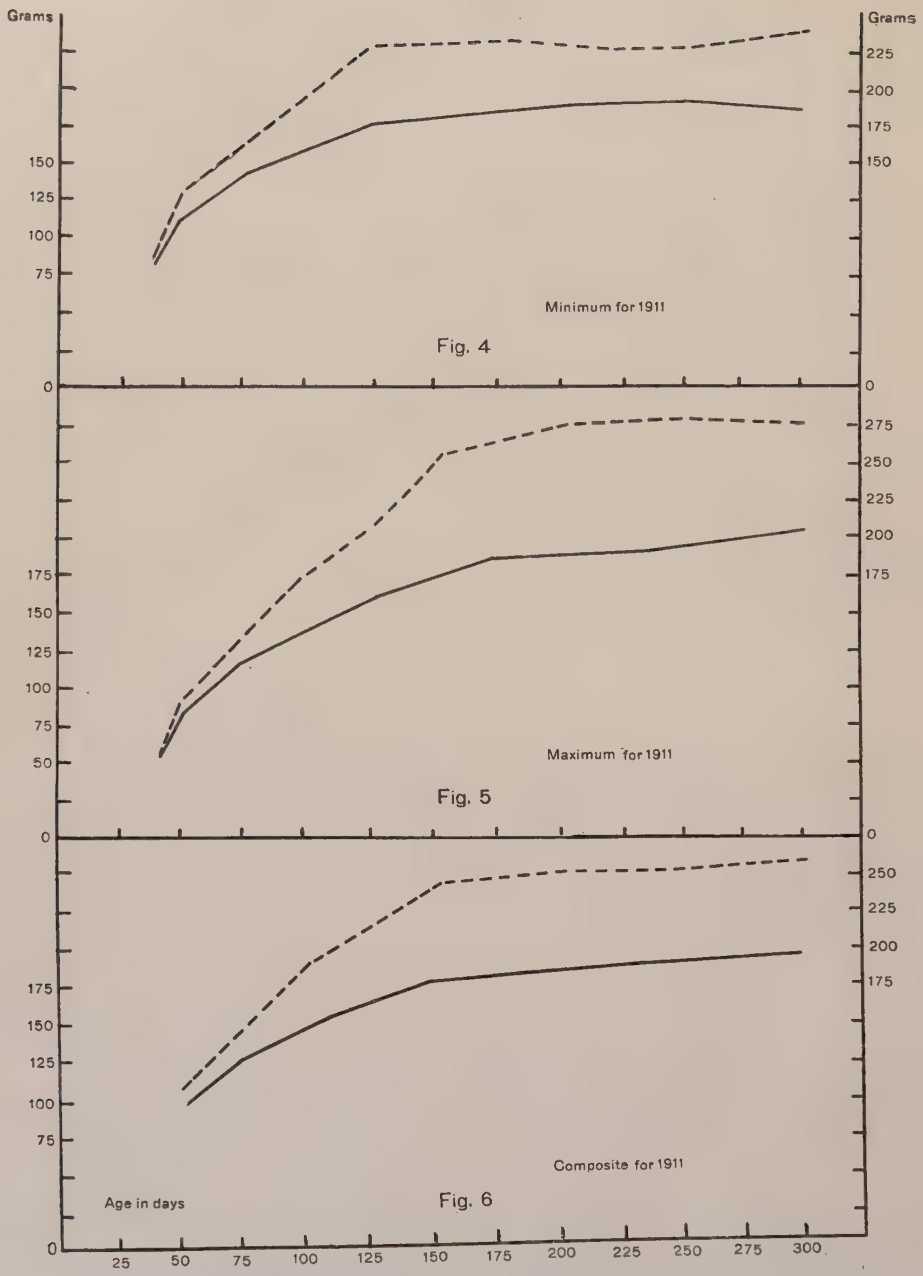
TABLE 13

Semi-spayed albino rats. Data from which the composite graph for 1910 and 1911 was plotted. Average weights of 25 operated and 23 controls

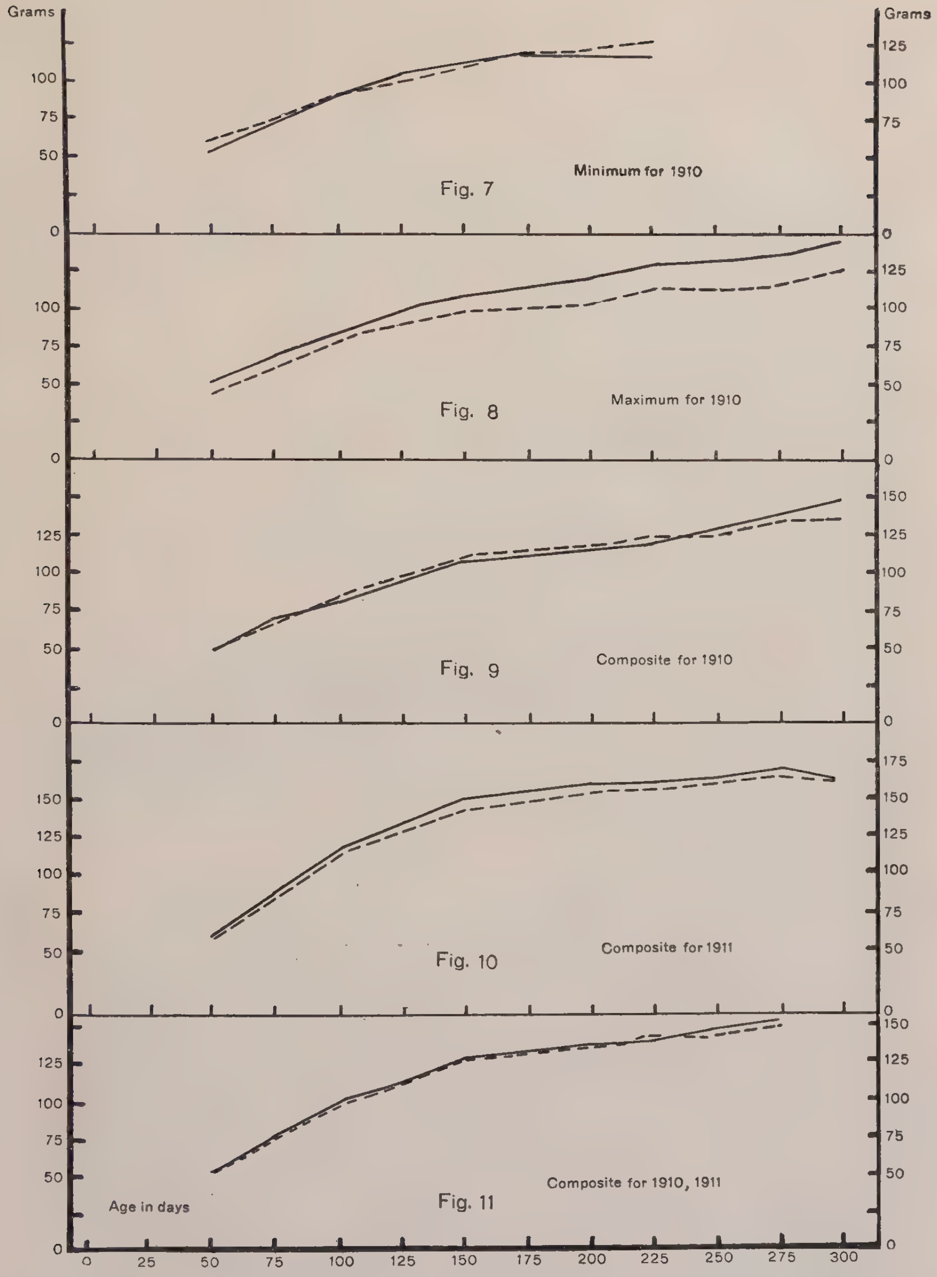
AGE IN DAYS	OPERATED	CONTROLS	AGE IN DAYS	OPERATED	CONTROLS
	grams	*grams*		*grams*	*grams*
50	53	54	175	132	133
75	78	79	200	136	137
100	100	100	225	141	141
125	114	115	250	143	147
150	126	128	275	150	152



Figs. 1 to 3 Showing the growth of spayed albino rats according to age. Solid line ——— for controls, broken line - - - - for operated animals. Figure 1 based on table 3, figure 2 based on table 4, figure 3 based on table 5.



Figs. 4 to 6 Showing the growth of spayed albino rats according to age. Solid line ——— for controls, broken line - - - - for operated animals. Figure 4 based on table 6, figure 5 based on table 7, figure 6 based on table 8.



Figs. 7 to 11 Showing the growth of semi-spayed albino rats. Solid line ——— for controls, broken line - - - - for operated animals. Figure 7 based on table 9, figure 8 based on table 10, figure 9 based on table 11, figure 10 based on table 12, figure 11 based on table 13.

OBSERVATIONS ON SPAYED RATS

The composite graph (fig. 1) representing the series of 1909, plotted from the combined weights of the six litters of this series, shows that while the average weights at the beginning were the same, the lines of growth soon separated and at the termination the spayed rats were 54 grams or 30 per cent heavier than the controls at 275 days of age.

In 1910 the colony as a whole was not in such a vigorous state as in the previous year, the animals not growing so large nor living so long in a healthy condition. The composite graph for this series (fig. 2) shows that although the animals did not gain the weight of the previous year, yet at the termination of the graph the two lines of growth were 22 grams apart, the spayed having gained 17.1 per cent at 225 days of age.

In 1911, the colony then being in an excellent condition, the graphs for growth proved to be more satisfactory. The minimum record (fig. 4) shows the rats to have had the same weight at the start, but at the termination the spayed were 46 grams or 27.6 per cent heavier, while in the maximum record (fig. 5) though the controls were slightly heavier at the start, the spayed soon surpassed them and at the termination were 66 grams or 33.3 per cent heavier.

The composite for this series shows the average gain of the spayed to have been 30.9 per cent at 300 days of age (fig. 6).

The composite graph representing the average for the three series, 1909, 1910, 1911 at 225 days of age (fig. 3), the age attained by the least successful series in 1910, shows the percentage of gain of the spayed over the controls to have been 24.8 per cent.

The greater body weight of the spayed rats which is thus shown, may be due either to a general overgrowth of the heavier animals or to the deposition of fat, or to both these causes. The series of 1910 and 1911 only are available for this test, the necessary measurements not having been made in the first series of 1909.

In the case of the two series used, the body length of the spayed animals is greater in ten out of the total of eleven litters, the average excess in body length being 3.4 per cent, the body length of the controls being taken as the standard. This excess in body length would call for an excess of 12.0 per cent, in body weight. At the time of maximum weights the spayed animals of the two series surpassed the controls in body weight by 23.5 per cent, and at the time of killing, when some of the spayed animals had lost weight through lung infection, by 18.1 per cent. The difference between the 12 per cent called for by the difference in body length and either of these values just given, must therefore be credited to the deposition of fat, and it is to be observed that the spayed animals show more fat at autopsy.

In the presence of such results from spaying, it became of interest to learn what semi-spaying would effect, so a series of experiments extending over two years was undertaken, in which 48 rats were used, 25 being operated upon and 23 kept as controls.

OBSERVATIONS ON SEMI-SPAYED RATS

The graphs representing the semi-spayed rats, or those animals from which either the right or left ovary alone had been removed, show that the absence of one of these glands does not modify the general body growth of the operated animal at all, their line of growth in weight corresponding very closely to that of the controls, and their body length being similar. Figures 7, 8, 9, 10 and 11 give the graphs for these experiments. Figure 7 shows the graph giving the minimum deviation for 1910, figure 8 the maximum for 1910, figure 9 the composite for 1910; figure 10 shows the composite for 1911, and figure 11 the composite for all the litters, 1910 and 1911, combined.

An examination of these graphs might lead one to suppose that the removal of only one ovary actually retarded growth in the animal so treated, the control rats so often being slightly heavier at the termination of the experiment. I do not think this is the case, however, the graphs so crossing and recrossing and in the composites being separated at any time to such a slight extent, that this relation is most probably due to merely incidental influences.

CONCLUSIONS

No literature on the effects of spaying on the growth of animals, exclusive of that on fat formation, has been found.[1]

These experiments, made as they were during three successive years and yielding in each year similar results, indicate that the ovaries act in a way slightly to retard growth in length and also to inhibit fat formation.

The first observation on the growth in body length after spaying is new, but the second, on fat formation, is but an extension of our previous knowledge that spaying, the menopause and gestation, representing as they do either physical or physiological removal of the ovaries, tend to cause both in man and other mammals an excess formation of fat. In the case of the semi-spayed rats, the observation that growth is not influenced by the operation is also new. It is interesting to note that the remaining ovary thus appears to be able to exercise as full control as both ovaries together, but in doing this it hypertrophies to twice its normal size. The further discussion of this hypertrophy of the ovary in the semi-spayed rats and the condition of some other organs in the spayed and semi-spayed, will be taken up by Dr. Hatai, who made the autopsies on the animals.

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[1] Löwy and Richter: Zur wissenschaftl. Begründung der Organtherapie. Berl. klin. Wochenschr., 1899. Diminished oxydation accompanied by fat deposition—abstract in Bernbaum, p. 30.

ON AN ABNORMAL SPECIMEN OF ROCCUS LINEATUS WITH ESPECIAL REFERENCE TO THE POSITION OF THE EYES

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The Biological Laboratory of The Johns Hopkins University

SIX FIGURES

In this paper I intend to show the secondary causes for the external appearance of the head of the fish in question; but beyond demonstrating that the primary cause must have taken effect very early in the life of the fish, most likely during its embryonic existence, it is impossible to arrive at any really fundamental cause. The latter without doubt can be approached only by purely experimental work upon the fish embryos, either by operative alterations similiar to the work of Dr. Lewis or by chemical changes due to alterations in the composition of their surrounding media, as in the work of Dr. Stockard. The value of the paper lies in its ability to add an additional monster to the list of those needing an explanation and additional evidence of functional adaptation. Since its value, therefore, varies directly with the accuracy of the description, I have taken pains to be as faithful to the original head as possible.

For the sake of clearness, I shall constantly compare the anomaly with a normal head from a fish of the same size and species. The fish weighed two and three-quarters pounds. Posterior to the gills there was no apparent variation in form or even in coloration. However, just a glance at the head will convince one at once that some serious changes have taken place (fig. 1). Instead of the gradual sloping of the dorsal and ventral surfaces to meet in a fairly sharp point anteriorly, at the front of the mouth, the ventral surface continues forward only rising very slightly while the dorsal surface ends abruptly just above the eyes making practically a right angle with the front of the head which is, in this case, broad and flat. Consequently the upper jaw extends only slightly in front of the eyes, to no extent occupying its normal position above the lower jaw. The tongue, however, protrudes to its usual length, lying exposed on the floor of the mouth. As a result of this position it had undergone some modifications, for it was slightly pigmented over its exposed portion and its upper surface was covered with fine scales set similarly to the regular scales which cover the skin, that is, so as to offer no resistance to a body moving from the anterior toward the posterior end of the body. They were not of the nature of true cycloid scales but merely a horny development of the papilla. They did not correspond, however, to teeth such as are normally present on the tip of the tongue of salmon and some other teleosts. Both the pigment and the scales, no doubt, were secondary protective adaptations, being absent normally. The position of the jaws prevented complete closure of the mouth (fig. 1). The nostrils had almost disappeared instead of remaining the prominent feature they are seen to be normally (fig. 4). Perhaps the most striking thing in the whole appearance is the peculiar protrusion of the eyes. They seem to be literally popping out of the head. It is also to be noted that the eyes have been brought around more to the front, approaching a binocular arrangement. Normally the eyes lie flush with the sides of the head and, blending more or less with the general outline, do not attract one's special attention. A further comparison of the accompanying plates will bring out other though minor differences in the external form.

In order to see the underlying fundamental changes which are responsible for these external appearances, a study of the bony structures of the head is necessary. The squareness of the front of the head is due to the frontal bone being bent down into more or less of a right angle at a point just above the middle of the interorbital space (figs. 2 and 5). Another change which must have occurred along with this is the bending of the parasphenoid bone which forms the floor of the orbits. It has buckled up, so to speak, in the middle, thus causing its two ends to be brought together. The middle part may be seen (fig. 2) projecting up into the orbital spaces. These two changes have, by greatly diminishing the size of the interorbital spaces, forced the eyes into their unusual position. I take these two abnormal bones to be the most fundamental in causing the alterations in the shape of the head because of their critical positions in bridging the space, between the bones of the anterior and posterior parts of the cranium, occupied essentially by the eyes. Also because all the other changes follow naturally and are what we should logically expect after these two. This statement is not reversible, since it cannot be said of any of the other bones. Furthermore there is a time in the development of the embryo when the bending above described could readily take place. Just before the frontal and parasphenoid bones are laid down in membrane, the supraorbital and trabecular cartilages, which, in the chondrocranium, occupy positions similar to the two bones, are entirely removed, thus weakening the head at this point. The bending down of the anterior part of the cranium naturally affected the growth of the membrane bones in this region. The results may be best seen by comparing the two sets of bones in figures 3 and 6. Figure 3 includes all the abnormal membrane bones except those that form a part of the cranium proper (namely, the frontal, parasphenoid, and vomer) together with enough of the unaltered bones to show the contrast well. Figure 6 shows the same bones taken from the normal specimen. Both are mounted to show as nearly as possible their normal relations.

An interesting feature comes out here in the position of the teeth, which can be seen in the figures with difficulty, owing to their small size. The palatine teeth instead of developing along the whole, normally ventral edge (fig. 6, no. 5) are confined to only the extreme tip (fig. 3, no. 5) of that edge. They have not only vanished from here but are practically gone from the dentary also (fig. 3, no. 6). The vomer teeth are present—though this cannot be well seen in the photographs, unfortunately—and occupy their same position in the roof of the mouth but not with reference to the bone, for in order to keep its teeth where they could be of service, that part of the vomer in which they are rooted has had to shift its position in relation to the rest of the bone until it is now approximately ninety degrees away from its normal position (fig. 2). These points would seem to indicate that the cause, whatever it was, permitted these ultimate changes to take place gradually.

A few things which throw light on the time at which the changes began to take place should form a fitting end to the paper. The cause or causes were most likely prior to the time of development of the maxillary, premaxillary, palatine and other membrane bones of this region for they conform exactly in shape to that of the cranium, as previously mentioned. Since all the cartilage bones of the skull are perfectly normal and since their positions and general shapes are more or less previously determined by the cartilaginous cranium, it hardly seems likely that the cause was present in the germ cells themselves but manifested itself after the cartilage at least had been laid down. It is scarcely conceivable that any injury in after life, such as being bitten through the upper jaw, could have caused such fundamental changes. Further the chances are that any such late injury would have handicapped the fish too greatly after its brain had developed for it to readjust itself, as it must have done to attain the size indicated by a weight of two and three-quarters pounds, to normal life and thus remain a successful contestant in the struggle for existence, which we have every reason to believe is a serious one among the lower animals. This question of adaptation after such fundamental alterations in the structure of the head at least, is certainly an important one.

As to the frequency with which variations of this type occur, I can say little or nothing except that the dealer from whom I got this one said that he sees eight or ten 'pug-nosed' fish a season. But a fish dealer is hardly an authority of scientific importance.

BIBLIOGRAPHY

Lewis, W. H. 1909 The experimental production of cyclopia in the fish embryo (Fundulus heteroclitus). Anat. Rec., vol. 3.

Stockard, C. R. 1907 The artificial production of a single median cyclopean eye in the fish embryo by means of sea water solutions of magnesium chloride. Arch. f. Entwicklungsmechanik der Organismen, Bd. 23.

EXPLANATION OF FIGURES

1 Photograph of the abnormal head of Roccus lineatus. All the photographs are about two-thirds natural size.

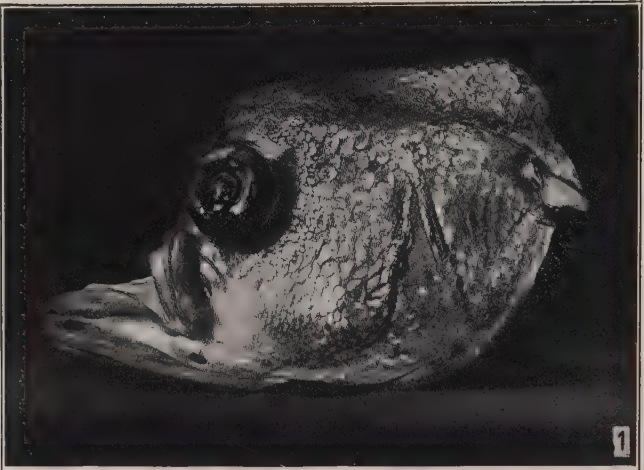
2 Photograph of the cranium bones of the abnormal head shown in figure 1.

3 Photograph of selected membrane bones from the same head: *1*, nasal; *2*, lachrymal; *3*, maxillary; *4*, premaxillary; *5*, palatine; *6*, dentary; *7*, articular; *8*, quadrate; *9*, hyo-mandibular; *10*, opercular.

4 Photograph of a normal head of Roccus lineatus.

5 Photograph of the cranium bones of the normal head in figure 4.

6 Photograph of selected membrane bones from the normal head. The bones are numbered the same as in figure 3.



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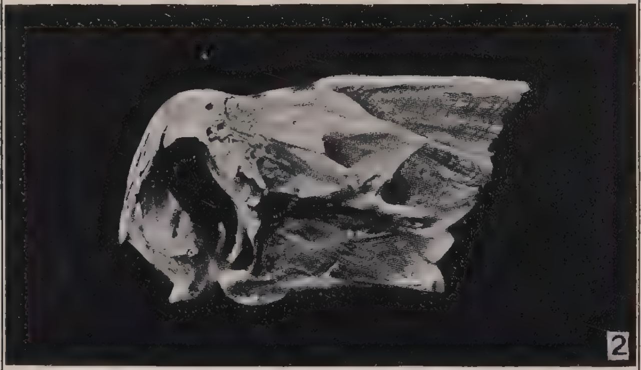

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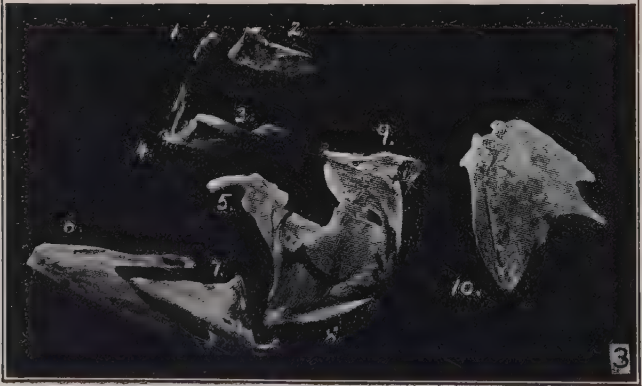

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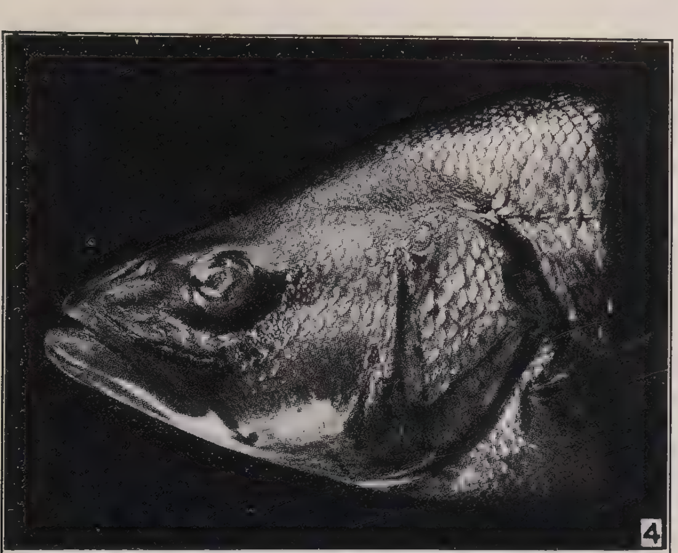

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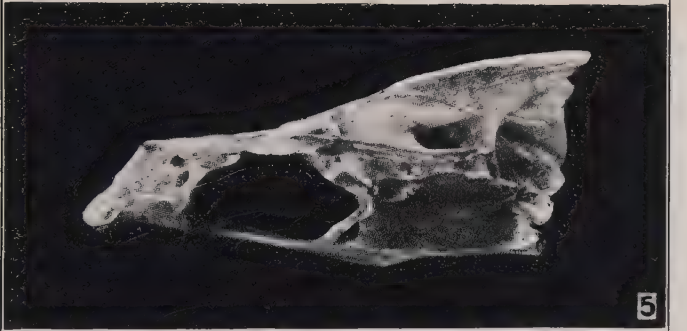

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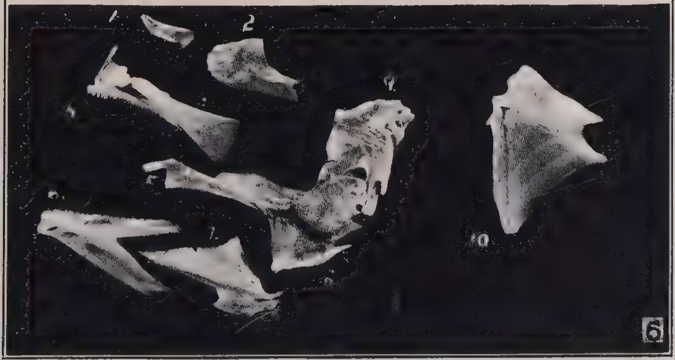

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MUSCULI STERNALES AND INFRACLAVICULARIS

N. W. INGALLS

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ONE PLATE

These anomalous muscles were observed in the dissecting room of the Medical School some time ago on the body of a well-developed adult male. On account of the relative infrequency of one of these muscles a brief descriptive note has seemed desirable.

MUSCULUS STERNALIS

The muscle on the left side arises by a broad, thin, tendinous origin from the sternal end of the sixth costal cartilage and from the pectoral fascia over the origin of the pectoralis major from the same cartilage. Opposite the fifth cartilage the tendon of origin gives way to a muscular belly which extends upward and inward, gradually becoming narrower, as far as the third interspace. Its tendon above can be traced mesially as far as the sternal synchondrosis in the median line and laterally, overlapping the origin of the pectoralis major, almost as far upward as the origin of the sternomastoid. The muscular belly at its widest point, in the fourth interspace, measures 2 cm. in width and from its lateral border there is given off opposite the fourth cartilage a small slip of muscle terminating in a small tendon in the fascia over the second interspace.

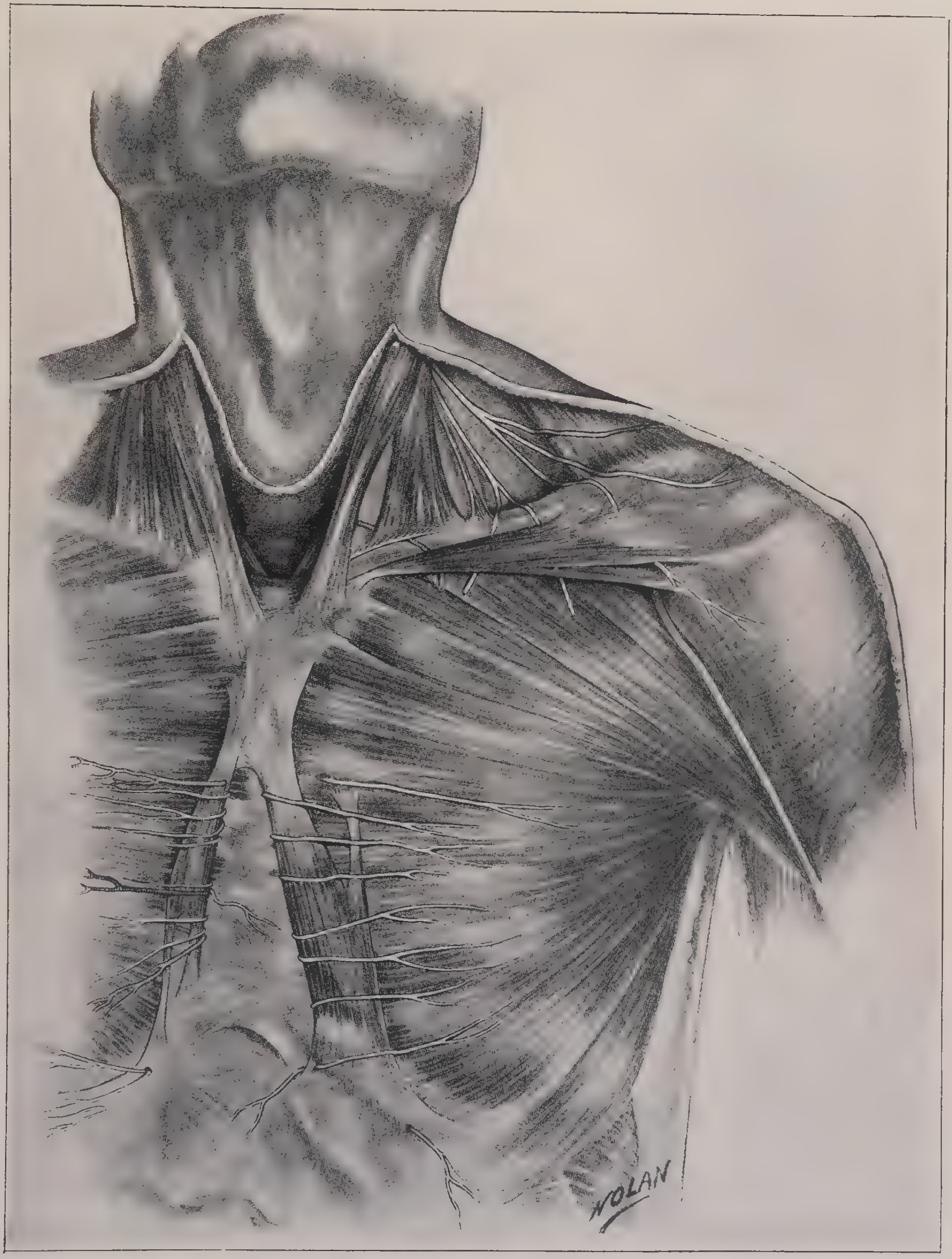
On the right the muscle is much smaller and more nearly parallel to the median line. It takes its origin by two small tendinous slips, the lateral slip from the inner end of the sixth cartilage, the mesial slip from the border of the sternum opposite the fifth cartilage. Just below the point of junction of the fourth cartilage with the sternum these two portions unite in a muscular belly 1 cm. in width which is replaced in the second interspace by a narrow tendon that can be traced upward, overlying the border of the sternum, to about the same level as the tendon on the left side.

The course of the anterior cutaneous branches of the second to the fourth intercostal nerves and a part of the fifth nerve on the left side is altered by the presence of the muscles (cf. Eisler, '01). The same applies also to the perforating branches of the internal mammary artery for the corresponding interspaces. Both nerves and vessels pierce the pectoralis major, run inward over the border of the sternum underneath the musculus sternalis and then bend sharply outward again, superficial to this muscle, to reach their termination in the skin. One of these nerves, however, in the second left interspace, takes its usual course directly outward and on the right side at the same level the tendon of the muscle is pierced by a small artery. The nerve supply was undetermined, probably from the external anterior thoracic nerves (Eisler '01, '12).

MUSCULUS INFRACLAVICULARIS

The other muscle with which this paper is concerned is far more infrequent in its occurrence (Eisler '12). It is the musculus infraclavicularis of v. Bardeleben, the "tenseur de l'aponévrose sous-claviculaire antérieure" of Testut and LeDouble. It is the representative of a rather variable class which take their origin from some part of the ventral surface of the clavicle, usually near its sternal end, and terminate more or less indefinitely in the pectoral or deltoid fascia.

In this case the muscle arises by a short, narrow tendon from the anterior sterno-clavicular ligament. It very soon becomes muscular, passing outward and slightly upward, its upper border parallel to and overlapping the clavicle, its lower border is practically horizontal. In form it is triangular or fan-shaped with its narrow apex internal. The uppermost fibers terminate by very short tendons on the ventral surface of the clavicle just outside the middle. The lower and intermediate fibers become tendinous in the infraclavicular fossa, the former,


NOLAN

separated externally from the rest of the muscle by a branch of the supraclavicular nerves, are lost in the fascia over the inner margin of the deltoid, the latter, forming the bulk of the muscle, end in the deltoid fascia immediately below the outer end of the clavicle. As a whole the muscle measures from 10 to 11 cm. in length and 1.5 cm. in width at its middle. It overlies and conceals the clavicular origins of both the pectoralis major and deltoid; under it pass branches of the supraclavicular nerves, one branch pierces its outer end twice and a small artery also passes beneath its inner end. Its nerve supply was not determined, but is stated by Huntington to be a branch of the external anterior thoracic nerve and the muscle is doubtless a derivative of the pectoralis major.

LITERATURE CITED

EISLER, P. 1901 Zeitschrift für Morphologie und Anthropologie, Bd. 3.
1912 In Bardeleben's Handbuch der Anatomie des Menschen, Die Muskeln des Stammes.
TESTUT, L. 1884 Les anomalies musculaires chez l'homme.
LEDOUBLE, A. F. 1897 Variations du système musculaire de l'homme.
HUNTINGTON, G. S. 1912 Quoted from Eisler.

THE MORPHOLOGY OF THE SEMINIFEROUS TUBULES OF MAMMALIA

PRELIMINARY NOTE

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Department of Histology and Embryology, University of Michigan

FIVE FIGURES

At the Cleveland meeting of the American Association of Anatomists, (1912–1913), Curtis[1] reported on wax plate reconstructions of the seminiferous tubules of the white mouse, presenting figures of a model of an entire tubule having an actual length of somewhat over 13 cm. The tubule completely reconstructed presents the form of an arch, the two ends of the arch lying in close proximity, each terminating in a tubulus rectus attached to the rete testis. In the course of the very thorough study which must of necessity be given to the series of sections in the preparation of drawings on which the reconstruction is based, it became evident that the testis in question contained no seminiferous tubules terminating in blind ends, and that anastomosis between tubules was very limited. Only one branching tubule was disclosed and on graphic reconstruction of this tubule it was found that each of the three branches terminated at the rete testis in tubuli recti. In the entire series of sections of the testis in question there were found but thirty-three tubuli recti, from which it appears that this testis contains but sixteen tubules, one of which is branched and terminates, as above stated, in three tubuli recti. These results, which are so at variance with the usual conception of the form and course of the mammalian seminiferous tubule, made it desirable to extend these observations to other forms, to determine whether the findings in the mouse testis would admit of generalization or pertained only to the form studied. The time involved in making the necessary drawings and wax reconstructions of the very long and coiled seminiferous tubules of adult mammalia is so great that it occurred to us that it might be possible to ascertain the main facts concerning the form and length of the mammalian seminiferous tubules by the less time consuming though perhaps more difficult process of maceration and teasing. For nearly all the known facts pertaining to the form, length and course of the mammalian seminiferous tubule we are indebted to the observations of the earlier investigators made on macerated and teased material. Successful teasing is dependent on the thoroughness and the uniformity of maceration of the tissue to be teased. Huber[2] has shown that by injecting a concentrated solution of hydrochloric acid into fresh tissues and then placing the injected tissue in a similar acid solution, a much more thorough and uniform maceration could be obtained than is the case when the tissues are placed directly into the macerating fluid as is the usual procedure.

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[1] George M. Curtis, Reconstruction of a seminiferous tubule of the albino mouse.

The method as applied to the study of the testis tubules is as follows: A cannula was inserted into the lower abdonimal aorta and the femoral vessels clamped just beneath the inguinal ligament. A 75 per cent solution of hydrochloric acid was then injected as rapidly as possible and under a pressure of about twenty to twenty-five pounds, the pressure being maintained until the parts appeared well injected, or until there is a rupture, which is not unusual. A few moments after the injection is completed the testes were removed and placed in a seventy-five per cent solution of hydrochloric acid in which they remain for from three to four hours. It is advisable to inject several animals at the same sitting and remove portions of the material from the macerating fluid at different intervals. The optimum degree of maceration can only be approximated, the extent of injection and other factors not readily controlled influencing the time required for thorough and uniform maceration. When the desired degree of maceration is thought to have been reached, the tissues are transferred to distilled water, in which they remain for from twenty-four to forty-eight hours. It is best to transfer the tissues from the acid to distilled water gradually and slowly, this by pouring off in part the acid and then filling the dish with distilled water and repeating the process until all of the acid has been removed. The distilled water is changed at frequent intervals during the first few hours. After a thorough washing in the distilled water the tissues are transferred to Mayer's hemalum solution in which they remain from twenty-four to forty-eight hours and are then transferred to tap water. The hemalum solution not only stains the tubules so that they may be followed the more readily while teasing but also hardens the tissue. Before the final teasing is undertaken the stained tissue pieces are transferred for several hours to a 0.5 per cent solution of ammonium hydrate. This develops the stain to a rich purple blue, clears the tissue and slightly softens the tubules so that they become quite pliable. The final teasing is carried on under the stereoscopic binocular. With thoroughly macerated, well stained and sufficiently ammoniated tissue pieces at one's disposal it is not so difficult to tease out complete seminiferous tubules if the teasing is carried out in shallow Petri dishes with sufficient quantity of distilled water to enable the teased portions of the tubule to float about freely. We have experienced, however, great difficulty in attempting to make permanent mounts of such preparation. The method which has given us the best results, after many others were discarded as unsatisfactory, is the following: The larger pieces of testis tissue are separated in relatively large quantities of distilled water into masses comprising single tubules or tubule complexes (see below). The smaller pieces thus obtained are then transferred to a large slide, the edges of which have been built up by means of melted soft paraffin until a well is formed holding a layer of distilled water having a depth of from 3 mm. to 5 mm. The tubule may now be teased out completely, all of the coils separated so as to admit of moderate extension. The teased tubule or tubule complex is now arranged as desired in the final mount. The water in the paraffin well is then very carefully drawn off by means of a fine pipette or strips of filter paper until the teased tubule rests upon the slide. The paraffin case is then removed, the slide cleaned and placed on the warm oven to hasten the evaporation of the water adhering to the tubule. If care be taken a stage is reached in which the tubule will adhere to the slide sufficient to admit of mounting, without showing distortions consequent to complete drying. The tubule may now be mounted under a cover glass coated with a layer of glycerine, lowered very slowly from one edge. The method is not simple, requires time and patience, but with it results may be obtained, as here reported. In macerated material details of cell structure cannot be made out, the method is, therefore, not applicable for ascertaining the length of the spermatogenetic wave. The space relations of the coils of a given tubule are of necessity destroyed after complete teasing. The length, general course and relations of tubules, their relation to the rete testis, branching and anastomosis are factors which can be determined in teased preparations.

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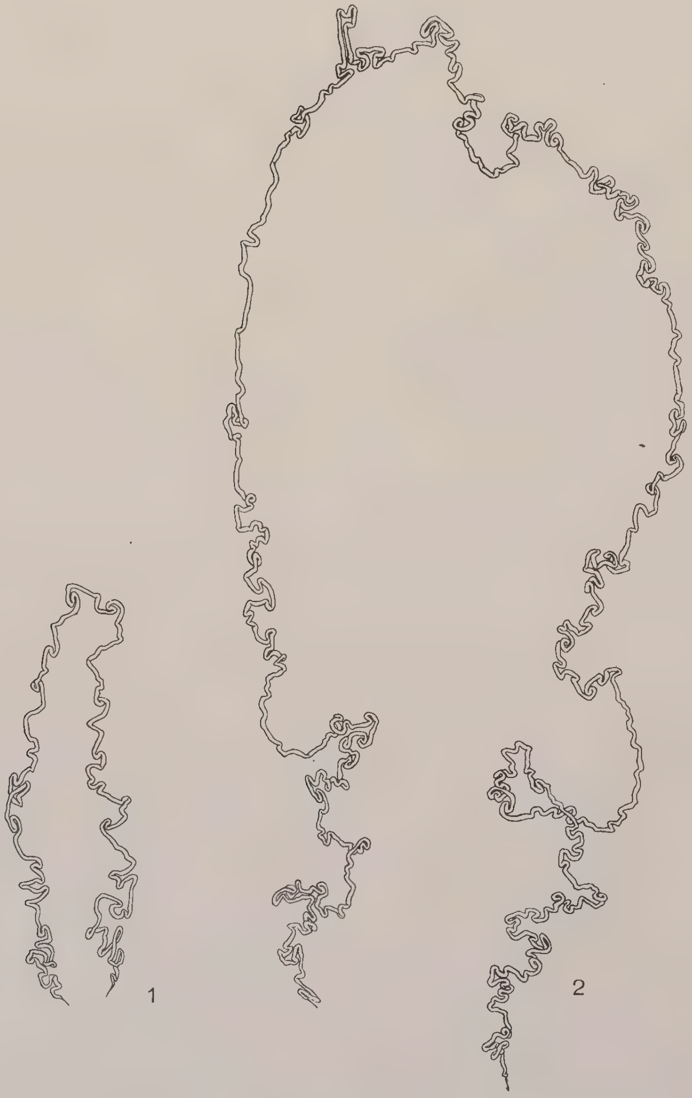
[2] G. Carl Huber, A method for isolating the renal tubules of mammalia. Anat. Rec., vol. 5, 1911.

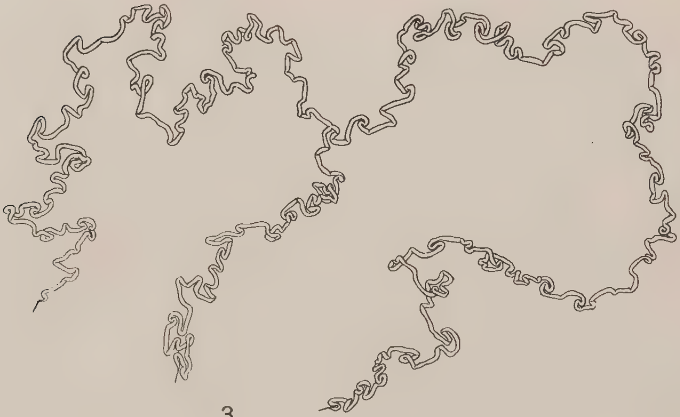
In this preliminary note we shall deal with observations made on isolated seminiferous tubules of adult rabbits. In a more complete publication, in which the literature bearing on this subject will be given consideration, one of us (Curtis) will report on reconstructions and teased preparations of the seminiferous tubules of several mammals. This work so far as completed, it may here be stated, confirm the results here recorded.

The seminiferous tubules of the rabbit appear to be arranged in the form of lobules having irregular pyramidal shapes, their bases bordering the tunica albuginea. These lobules may readily be seen in cross or sagittal sections of fixed material. The lobules are separated by more or less well defined strands of connective tissue, continuous with the mediastinum on the one side and the tunical albuginea on the other. On attempting to separate these lobules in the preliminary teasing of the larger masses of macerated testis tissue, it became evident that what appeared as a lobule could not be completely separated without tearing tubular structures, that apparent lobules were connected with adjacent lobules by tubules which passed from one to another. In well macerated tissue it is relatively easy to separate these so called lobules in the region of the mediastinum, especially if care be taken to break the tubuli recti, which form the apices of the lobules, at their point of connection with the rete testis. If the lobules be now separated from the region of the mediastinum toward the periphery of the testis it will be found that certain ones do not reach the periphery but become connected through a bridge of coiled tubules to an adjacent lobule which in turn may be traced toward the rete testis, ending in a tubulus rectus; others with similar general course may extend toward the periphery of the gland and reach the region of the tunica albuginea It is possible to separate from tissue masses taken from any portion of the testis such coiled tubule masses arranged in the form of an arch or inverted U, the ends of the pillars of the arch terminating in tubuli recti attached to the rete testis. Such arch shaped coils of tubules, consisting apparently of two lobules united at the periphery, when completely teased out show a single tubule, both ends of which terminate in a tubulus rectus attached to the rete testis. They vary greatly in length and in the degree of coiling and folding of the constituent tubules. Numerous such tubules, completely teased and mounted, and taken from the testes of several rabbits, have been observed. They form the simplest type of the seminiferous tubule of the rabbit and are in every way comparable to the tubule of the mouse testis reconstructed in full by Curtis. In figures 1 and 2 are shown two seminiferous tubules of this simpler and more prevalent type, completely teased and mounted. These and the other tubules figured were sketched with the aid of the camera lucida at a magnification of 25 diameters, reduced to the present size in the reproduction. Each tubule, as may be observed, begins and ends in a tubulus rectus. The tubule shown in figure 1, one of the shortest teased, presents an actual length of 9.1 cm., while the tubule shown in figure 2, one of the longest simple tubules teased out completely, presents an actual length of 30.2 cm. The measurements here given were obtained by measuring the length of the tubule as presented in the enlarged drawing by means of a map-measurer, the length thus obtained being then divided by 25, the magnification used in making the drawing.



Figs. 1 and 2 Seminiferous tubules of adult rabbit, arranged in the form of an arch, with ends attached to rete testis. × 2.5.

In presenting these measurements we are aware of slight sources of error, due largely to the fact that it is difficult to portray accurately the exact length of a coil which has its direction up and down in the field of vision. Furthermore, there is evidence of slight shrinkage when the tissues are injected and placed in hydrochloric acid, perhaps compensated during washing in distilled water. The ammoniated water causes a slight swelling of the tissue, and this we are forced to disregard in making the measurement. The measurements given appear to us approximately accurate, we believe more so than those given by earlier observers. Our observations on teased preparations show that the seminiferous tubules of the adult rabbit do not present blind ends nor do they show longer or shorter diverticuli nor nodular enlargements. In stained tissue the observer is able to trace the course and outline of a given tubule much more clearly than is the case in unstained tissue. We have often noted what we are inclined to believe might readily be regarded as diverticuli or nodular enlargements were our observations confined to unstained tissue. The tubules often present very sharp turns, the two arms being parallel and in close relation. Such a sharp turn presented to view in such a way that one arm overlaps the other, may in unstained tissue readily simulate a diverticulum. When such a sharp turn is extended, the convex border appears to project as a nodular enlargement, which disappears when the parts are allowed to approximate their normal relations. A study of the numerous teased preparations has led to the conclusion that no seminiferous tubules of the adult rabbit, whether of the type of a simple arch, figures 1 and 2, or of a more complex type with branchings and anastomoses as in figures 3, 4 and 5, can be regarded as teased completely unless all of the free tubular ends can be traced to a termination in a tubulus rectus. This has been our criterion in determining whether the more extensive tubular complexes about to be described are to be regarded as teased completely. In the preliminary teasing of the larger masses one frequently meets with tubular complexes in which more than two so called lobules are joined together. On complete teasing of such portions one meets here and there, and practically at all



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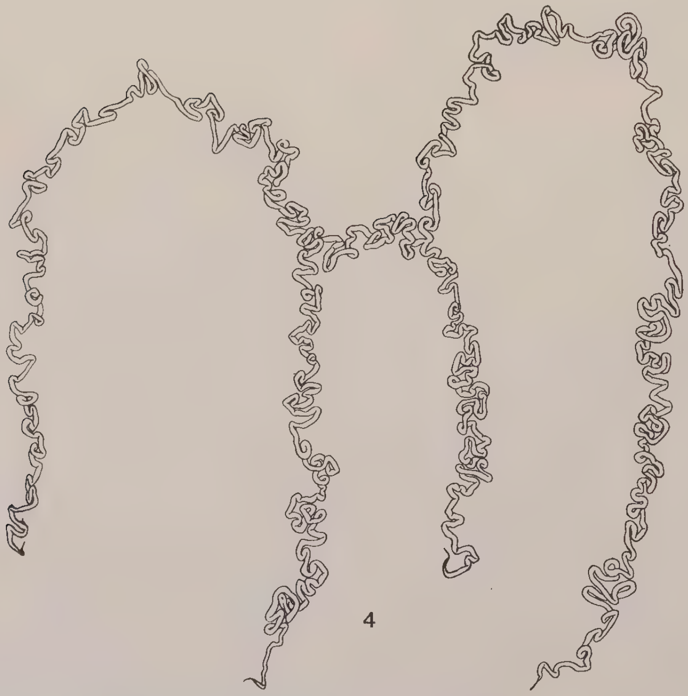

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Fig. 3 Seminiferous tubule complex of adult rabbit, showing junction of three tubules, each attached to rete testis. × 2.5.

Fig. 4 Seminiferous tubule complex of adult rabbit showing junction of two arched tubules. × 2.5.

levels, though most frequently toward the periphery, distinct Y-shaped or T-shaped branching, through which several arch systems are linked together. The extent to which this branching and anastomosis may take place is difficult to determine since the connections between the lobules are very readily broken and loops which reach the tunica albuginea are very easily torn during the manipulation necessary for the removal of the tunica and the teasing required to separate the so-called lobules. Many broken ends are encountered in attempting to isolate completely tubule complexes with a number of anastomoses, broken ends very often not evident until the teasing is practically complete. We present here a number of types of tubule complexes with anastomoses of tubules regarded as teased completely, in that in each case each tubule was traced to its termination in a tubulus rectus, ending in the rete testis. The figures are so clear that only a brief word of explanation is deemed necessary. In figure 3 is shown a tubule complex in which three so-called lobules are joined by means of a T-shaped division. The region of the division presents no structural peculiarity, each of the three tubules show functional activity in the region of joining. This statement, however, is based on observations made on sections, rather than on teased preparations, though even in the latter the structure presented in the immediate vicinity of the division is very similar to the other parts of the tubules. As may be seen in the figure, each of the three tubules ends in a tubulus rectus, which in the unteased mass was in close proximity with the other two, and joined the rete testis. The actual length of the tubule complex, measured as above described, we find to be 26.7 cm. In figure 4, are shown two arched tubules, in general arrangement very similar to those shown in figures 1 and 2, but linked by means of a short transverse bridge. Configurations of this type are not frequently met with owing perhaps to the fact that the narrow transverse bridge is readily broken during manipulations necessary to separating the mass from the testis tissue. The mass from which this tubule complex was teased presented four so-called lobules folded together like a closed book, the transverse bridge being hidden and embedded in one of the lobules and not evident until the teasing was practically completed. Each of the four tubular ends terminates in a tubulus rectus, which join the rete testis in close proximity. At the right of the figure the junction of three tubules is favorably placed, at the left of the figure a like junction is obscured. While still floating freely in the water it was possible to move this tubule complex about, cause tension here and there and determine with certainty the existence of the anastomoses. So with other tubule complexes completely teased. After the water has been withdrawn, so that the tubule complex rests upon the slide, the slightest tension usualy results in a tear. Experience, therefore, leads one to be content with the position assumed by the tubule complex after the withdrawal of the water, even though the resulting figure may not be as clear as is desired. The actual length of this tubule complex, which was removed from the middle third of the testis, in which region are found the largest tubules, proves to be 38.5 cm.

In figure 5, is shown a prevalent type of tubule complex, a type, however, which is very difficult to tease out completely. Many masses recognized as presenting similar tubule complexes have been teased, only to find here and there a broken tubular ending, indicating that only a portion of the complex had been separated from the testis tissue. As stated above, the evidence seems conclusive that only tubules ending in tubuli recti can be regarded as completely teased. A tubule broken at a sharp turn often simulates very closely one terminating in a blind end, especially if the basement membrane seems to pass around the broken end. Closer study, and especially turning over the supposed blind end, reveals a broken surface, admitting of a correct interpretation. In figure 5 are shown seven tubules linked together. The mass from which this complex was teased, when partly separated and unrolled, presented seven slender so-called lobules united at the periphery. After complete teasing it could be readily determined that all of the seven tubules were linked together through Y-shaped divisions of the tubule. In making a permanent mount of this tubule complex a slight shifting of tubule segments from the position originally given them

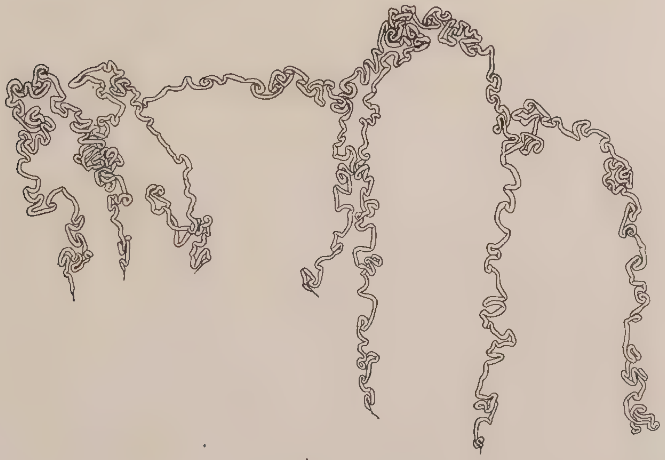

Fig. 5 Seminiferous tubule complex showing junction of seven tubules, each ending in a tubulus rectus and attached to the rete testis. × 2.5.

has led to the obscuring of certain of the junctions. In an attempt to straighten somewhat the second tubule from the left in this figure, this was torn from its attachment at the T-shaped division. This tear was disregarded in making the figure. The last tubule to the right does not show in the mounted preparation its termination in a tubulus rectus, which is folded under the tubule, yet was clearly evident after the completion of teasing. The other six tubules show clearly their termination in tubuli recti. This tubule complex was removed from the lower third of the testis and presents an actual length of 30.4 cm. We are convinced that the tubule complex shown in figure 5, does not show the extent of linking of tubules which may take place in the adult rabbit testis. In one preparation at least twelve tubules seemed joined together, although in this preparation certain of the tubules could be traced only for a short distance before a broken end was reached; others which could be completely teased terminated in tubuli recti. The difficulty met in separating the parts belonging to a single tubule complex, during the preliminary teasing of the larger masses of testis tissue, masses which are not sufficiently transparent to admit of transmitting even strong artificial light, leaves it largely to chance as to whether one obtains a complete tubule complex for the final teasing. Three of the six testes prepared for teasing proved to be well macerated. Preparations made of each of these presented the same general features. One was over macerated, teasing very readily, but the tubules were too soft to admit of the manipulation necessary for complete isolation. One rabbit, as was noted after completion of the hydrochloric acid injection, presented a very small cryptorchid on the left side, with the right testis slightly larger than one-half the size of a normal testis of rabbit of similar weight. The left testis was disregarded as it was found to be infantile, with very small tightly coiled tubules. The right testis was not very successfully macerated. From it, however, there was isolated a tubule complex, which though not complete, in that it was not possible to trace all of the constituent tubules to their termination in the rete testis through tubuli recti, presents clearly an extended anastomosis, such as has not been seen in what we regard as normal testes. In two regions of this tubule complex, toward the periphery, tubules were joined together so as to form two folded rings, to different segments of which were attached tubules extending to the rete testis. This tubule complex will be considered more fully by Curtis in a later publication. The question arises as to whether this somewhat unique arrangement may be regarded as characteristic of the incompletely developed state of the gland or merely a chance finding. It is regretted that the maceration of this gland was such that a more extended observation was not permitted. Judging from the teased preparation the gland in question seemed functional. Concerning the life history of this rabbit we have no data. The observations of Bremer[3] on the human seminiferous tubule, based largely on reconstructions of embryonic material, will be considered in the light of our work in a later publication.

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[3] John Lewis Bremer, Morphology of the tubules of the human testis and epididymis. Amer. Jour. Anat., vol. 11, 1910–1911.

As a result of our observations on the seminiferous tubules of the adult rabbit we feel warranted in presenting the following conclusions:

1. The seminiferous tubules of the adult rabbit present no blind ends, diverticuli, or nodular enlargements.

2. In their simpler form they are arranged in the form of an arch, the tubule beginning and ending in a tubulus rectus, each attached to the rete testis, both ends of the tubule having thus a functional connection with the rete.

3. The more extensive tubular complexes may be regarded as composed of a series of linked arches, joined through Y-shaped or T-shaped divisions of the tubules, the regions of the divisions showing no structural peculiarity, all the tubules ending in tubuli recti attached to the rete testis.

4. The extent of the linking of the tubules is difficult to determine. Observations show that from three to twelve tubules may thus be linked in one tubule complex.

5. The lobules evident in sections of the rabbit testis, or on macroscopic inspection, do not represent each a complete tubule, if a tubule be regarded as one beginning and ending in the rete testis, but represent a coil complex of a portion of a tubule as it passes from the mediastinum toward the periphery or from the periphery toward the mediastinum.

BOOKS RECEIVED.

DIE BIOLOGISCHEN GRUNDLAGEN DER SEKUNDÄREN GESCHLECHTSCHARAKTERE, Dr. Julius Tandler, Professor der Anatomie an der Wiener Universität und Dr. Siegfried Grosz, Privatdozent für Dermatologie und Syphilidologie an der Wiener Universität, Mit 23 Textfiguren, 169 pages including index, 1913. M. 8. Julius Springer, Berlin.

THE POSTURE OF SCHOOL CHILDREN, with its home hygiene and new efficiency methods for school training, Jessie H. Bancroft, assistant director physical training, public schools, New York City, illustrated, 327 pages including index, 1913, $1.50. The Macmillan Company, New York.

THE NARCOTIC DRUG DISEASES AND ALLIED AILMENTS, pathology, pathogenesis and treatment, Geo. E. Pettey, M.D., member, Memphis and Shelby County Medical Society, Tennessee State, illustrated, 516 pages including index, 1913, $5.00. F. A. Davis Company, Philadelphia.

THE CEPHALIC NERVES: SUGGESTIONS

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THREE FIGURES

The BNA term 'cerebral' as applied to the nerves of the head is a misnomer. There are only four cerebral nerves proper, although the nerve of taste may have cerebral terminals. Hardesty, in the anatomy of Morris, returned to the use of the old term 'cranial' in preference to 'cerebral' and rightly so, because the nerves distributed in the head do pass through openings in the base of the skull, and but four of them are attached to the cerebrum.

Furthermore, the cranial nerves need a reclassification. No author or publisher of a text-book of anatomy has yet been brave enough to replace the twelve pairs of cranial nerves with the nerves as they really exist. The time is propitious for some alteration because of the gross errors and apparent complexity that exist in an attempt to conform recent discoveries with old fashioned notions.

For instance, there are not two olfactory nerves but about forty, the olfactory bulb and tract being not a nerve but an outgrowth of the brain. Likewise, the optic nerve is not a nerve but another outgrowth of the brain: There is a retina which is a modified cerebral cortex, an association tract and a decussation, but no nerve proper. The first and second pairs of cranial nerves should therefore be described with the olfactory apparatus and the optic apparatus. The tenth and eleventh cranial nerves should not be considered with the nerves of the head, because they are distributed to the neck, shoulder and trunk, and form an intermediate stage between the cervical spinal nerves and cranial (why not cephalic?) nerves. Omitting these four pairs

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of nerves there remain but eight of the usually so-named cranial nerves. However, if only one cranial nerve be lost the classic twelve is broken and all indication by numerals may as well be discarded.

I therefore propose an alteration in the terminology of the present so-called cranial nerves in the following manner:

1. Call the nerves distributed in the head the *cephalic* instead of the cranial or cerebral nerves. The head includes the cranium and face, with the orbital, nasal and buccal cavities as a part of the latter.

2. Omit the olfactory and optic nerves and describe them under their proper apparatuses.

3. Omit the pneumogastric and spinal accessory nerves from the cephalic group because they belong to the spinal cord type, or may be considered as transitory nerves between the spinal cord and brain, and they are not distributed to the head but to the neck, shoulders and trunk.

4. Add three nerves to the cephalic group.

a. Add the motor root of the trigeminals, which is as much a separate nerve as the facial, the two supplying motion to the mandible and face, as motor reciprocal to the trigeminal which supplies sensation to the teeth and face. The name of the motor root of the trigeminal should be the masticator nerve (n. masticatorius), as given in the BNA, because it supplies the muscles of mastication.

b. Add the sensory part of the facial, including the intermediate nerve of Wrisberg, the geniculate ganglion containing the cells of origin of this nerve, and the chorda tympani, with its distribution in the tongue and palate. Call this nerve the glossopalatine nerve (n. glossopalatinus), as suggested by Hardesty. The work of Streeter, Cushing, Sheldon and others demonstrates that this nerve is only a segregated portion of the glosso-pharyngeal nerve in its ontogeny and phylogeny, as well as in its central and peripheral terminations, but its roundabout course necessitates a separate name.

c. Add the nerve of the semicircular canals, separating it from the nerve of the cochlea. Retain the name acoustic or auditory for the latter and give the former separately the name it bears at present, vestibular nerve.

5. Finally, omit the sympathetic ganglia of the head, especially the ciliary, sphenopalatine, otic and submaxillary, from the description of the cephalic nerves, and constitute them as a ganglionated cephalic plexus, including the sympathetic part of the geniculate, petrous and jugular ganglia, the prolongation upward of the cervical sympathetic system. This will be considered separately at the end of this study.

The nerves as rearranged may be enumerated as the cephalic nerves:

NAME	DISTRIBUTION	NATURE
Oculo-motor	eye muscle	motor
Trochlear or pathetic		motor
Abducens		motor
Trigeminal or trifacial	face	sensory
Masticator		motor
Facial		motor
Auditory or acoustic	internal ear	sensory
Vestibular		sensory
Glossopharyngeal	tongue, palate, etc.	sensory (mixed)
Glossopalatine		sensory (mixed)
Hypoglossal		motor

This is a more rational arrangement than that of the twelve cranial nerves, if only the grouping of the nerves of like distribution is considered and when it is kept in mind that the origin and central connections, course and distribution of each nerve is distinct, their individuality is apparent.

It may be well to give descriptions of the newly constituted nerves, the masticator nerve, the vestibular nerve and the glossopalatine nerve, although the masticator and vestibular nerves are so well known under the names of the motor root of the trigeminal, and the vestibular part of the acoustic, respectively, that only the glossopalatine nerve will be described in detail. Diagrams are given to illustrate the course and distribution of the masticator and glossopalatine nerves, and the ganglionated cephalic plexus and its connections. (figs. 1, 2 and 3).

The glossopalatine nerve

This nerve consists of four parts which have been recognized as parts of one nerve but not so described in the text-books. The four parts are the pars intermedia or intermediate nerve of Wrisberg, the geniculate ganglion, the chorda tympani and the palatine portion of the nerve. The nerve is apparently an aberrant part of the glossopharyngeal nerve. Its cells of origin are located in the geniculate ganglion, the peripheral processes

ABBREVIATIONS

a.d.t.n., anterior deep temporal nerve
a.t.n., auricular temporal nerve
b.n., buccinator nerve
c.p., carotid plexus
c.a., carotid artery
c.t., chorda tympani
c.b., communicating branch to middle cervical sympathetic ganglion
c.g., ciliary ganglion
c.t.n., caroticotympanic nerve (small deep petrosal)
c.c.p., carotid and cavernous plexuses
c.n., carotid nerve
e.p.n., external pterygoid nerve
e.c.a., external carotid artery
e.s.p.n., external superficial petrosal nerve
f.n., facial nerve
f.a., facial artery
f.n.f., facial nerve fibers
G.g., Gasserian ganglion
g.n., glossopharyngeal nerve
g.p. of g.g., glossopalatine portion of geniculate ganglion
gen.g., geniculate ganglion
g.s.p.n., great superficial petrosal nerve
g.d.p.n., great deep petrosal nerve
g.p.n., glossopalatine nerve
g.r., geniculotympanic ramus
i.c.t.n., inferior carotico tympanic nerve
i.c.n., internal carotid nerve
i.p.n., internal pterygoid nerve
i.m.a., internal maxillary artery
i.a.n., inferior alveolar nerve
j.n., jugular nerve
j.g., jugular ganglion
l.n., lingual nerve
mas.n., masseter nerve
my.n., mylohyoid nerve
m.m.a., middle meningeal artery
max.n., maxillary nerve
m.m., mandibular nerve
mas.n., masticator nerve
n. of p.c., nerve of the pterygoid canal (Vidian)
n.p., nodosal plexus
o.g., otic ganglion
oc.n., oculomotor nerve
op.n., ophthalmic nerve
p.i., pars intermedia
p.d.t.n., posterior deep temporal nerve
p.n., petrosal nerve
p.g., petrous ganglion
p.p., *of g.n.*, palatine portion of glossopalatine nerve
s.g., sphenopalatine ganglion
sub.g., submaxillary ganglion
s.c.s.g., superior cervical sympathetic ganglion
s.s.p.n., small superficial petrosal nerve
s.g., sphenopalatine ganglion
t.n., tympanopetrosal nerve
t.p., tympanic plexus
tym.n., tympanic nerve (Jacobson's)
tri.n., trigeminal nerve
v.n., vagus nerve

of which end in the anterior two-thirds of the tongue and the soft palate, and the central processes of which terminate about cells superior to the nucleus of termination of the glossopharyngeal nerve in the medulla.

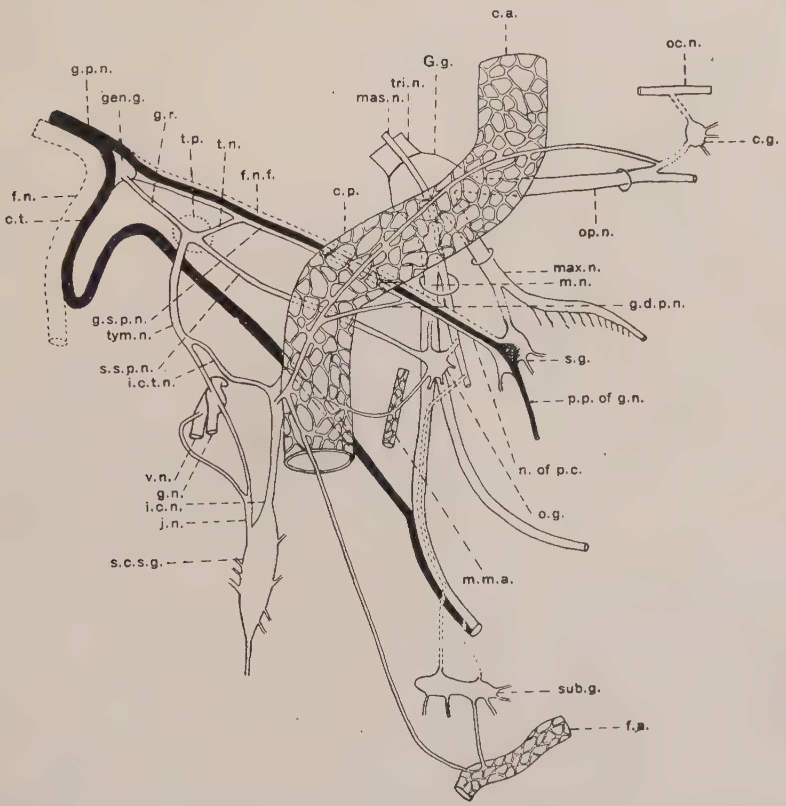

Fig. 1 Diagram showing the glossopalatine nerve and the ganglionated cephalic plexus. Each ganglion has three roots; the motor root is in broken lines, the sensory is in dotted lines and the sympathetic is in solid lines. Mesial view, left side.

The geniculate ganglion is embedded in the anterior border of the great bend of the facial nerve behind the hiatus Fallopii. It is somewhat triangular in form and at its three angles three nerves are found. Its external angle has the chorda tympani attached, its anterior angle is connected with the great superficial petrosal nerve, and its superior angle has the root of the inter-

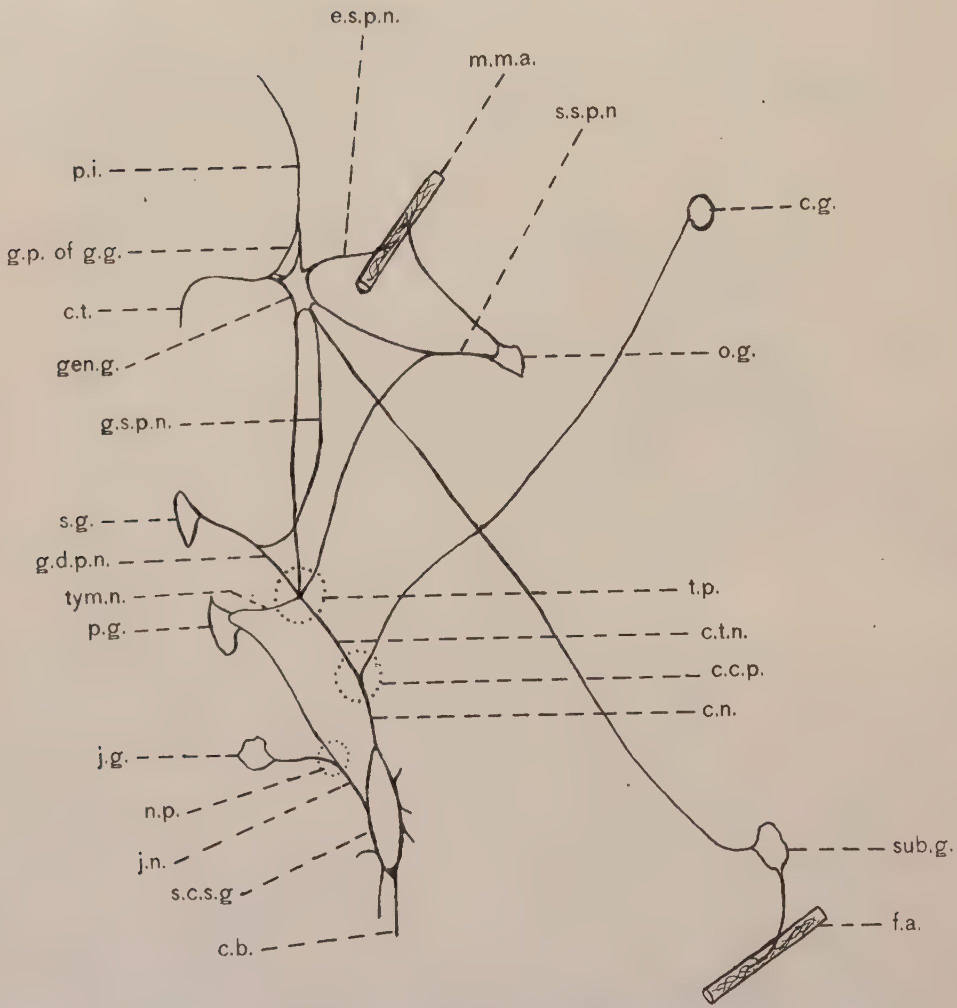

Fig. 2 Scheme to represent the continuity of the sympathetic connections of the cephalic ganglia (ganglionated cephalic plexus).

mediate nerve proper. A part of the geniculate ganglion belongs to the sympathetic system and will be described below with the ganglionated cephalic plexus.

The fibers of the intermediate nerve concerned in the glossopalatine nerve pass from the geniculate ganglion in the facial canal (aqueduct of Fallopius) inside the sheath of the facial nerve, which it leaves as it passes inward through the internal auditory meatus to turn slightly downward in the posterior fossa of the cranium. It enters the medulla immediately below the pons between the facial and auditory nerves, passes through the reticular formation inward and backward to terminate in the group of cells superior to the nucleus of termination of the glosso-pharyngeal nerve. In the internal auditory meatus the nerve gives two delicate filaments to the vestibular nerve. The intermediate nerve contains a few motor fibers probably acquired while it is in the sheath of the facial nerve. It also may contain secretory fibers from the medulla whose impulses reach via sympathetic neurones the glands and mucous membrane of the salivary apparatus.

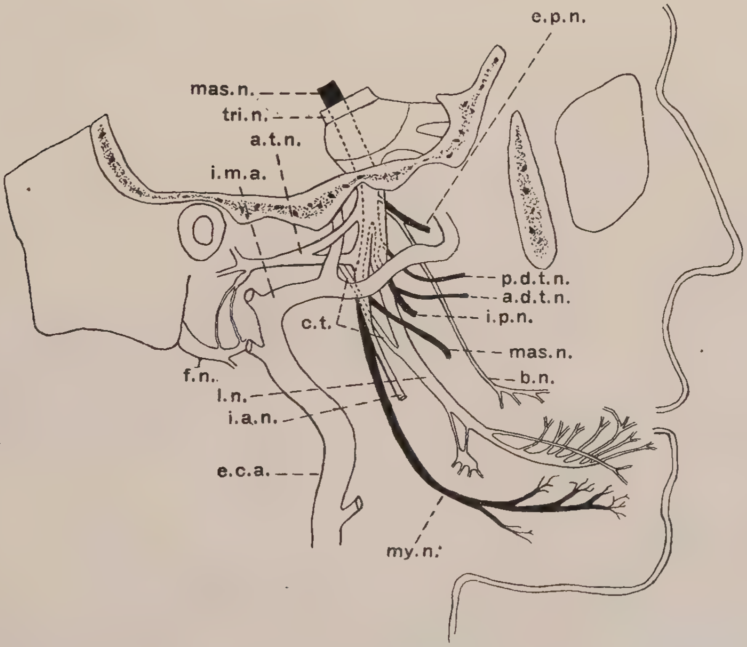

Fig. 3 Schematic representation of the masticator nerve (in black); modified from Spalteholz. Lateral view, right side.

The chorda tympani is so well known it need not be described. Other sensory fibers of the glosso-palatine nerve besides those of the chorda tympani rise in the geniculate ganglion and pass through the great superficial petrosal nerve and the spheno-palatine ganglion to the soft palate where they are probably connected with the peripheral taste organs found there, as well as serving as fibers of general sensibility for the palate.

Enough has been said to indicate the most essential changes to bring the nerves of the head up to date. There is one other change, a change in the hypoglossal nerve. The ansa hypoglossi or loop of the hypoglossal is not a part of this nerve and should not be included with it but instead should be described with the cervical plexus of which it is a part. The name ansa hypoglossi should be discarded and in its place the name ansa cervicalis substituted. Likewise the descendens hypoglossi and the communicans hypglossi should be altered to the descendens cervicalis and the communicans cervicalis.

Whether the suggestions here given be followed or not there can be no doubt that such changes would clarify and simplify the cephalic nerves. The removal of the ganglia and their connections from the facial, trigeminal and glosso-pharyngeal nerves, and so forth, simplifies these nerves, and the segregation of the masticator, vestibular and glosso-palatine nerves further simplifies the nerves with which they are usually described.

The ganglionated cephalic plexus (*figs. 1–2*)

The ganglia of the head receive and distribute three classes of fibers, motor, sensory and sympathetic. They do not belong to any one nerve or set of nerves, although they all have sympathetic connections and may be considered as the prolongation upward of the cervical sympathetic ganglia. They correspond both structurally and developmentally with the sympathetic ganglia, except those parts of the geniculate, petrous, and jugular ganglia which represent the dorsal root ganglia, or ganglia of origin of the sensory portions of the glossopalatine, glossopharyngeal, and pneumogastric nerves respectively. Some of these ganglia of the head are vagrant ganglia which separated from the embryonal semilunar or Gasserian ganglion at an early period of development—just as the sympathetic ganglia of the neck and trunk separated from the embryonal spinal ganglia.

These ganglia of the head with their connections may be conveniently grouped together as *the ganglionated cephalic plexus*, and may be said to consist of the ciliary, the sphenopalatine or Meckel's ganglion, the otic, the submaxillary, and a part of the geniculate, of the petrous and of the jugular ganglion.

Each ganglion may be said to possess a motor root, a sensory root, and a sympahetic root, and the ganglia act as relays and points of dispersal for these three sets of fibers. Motor impulses go to the eyeball, the palate, the middle ear and the pharynx; sensory impulses come from the same regions and from the lining of the mouth; and secretory fibers are distributed to the lachrymal glands, to the mucous membrane of the nose and mouth, pharynx and palate, to the parotid glands, and to the submaxillary and sublingual glands.

The superior cervical sympathetic ganglion gives off two large branches which pass upward to communicate with the ganglionated cephalic plexus. One of these, the carotid nerve, is the direct continuation upward of the gangliated cord, and through its branches, the caroticotympanic and the deep petrosal nerves, as well as through the plexuses derived from it, this nerve communicates with practically all the ganglia of the head. Another nerve from the superior cervical sympathetic ganglion, the jugular nerve, passes directly to the ganglia of the pneumogastric and glossopharyngeal nerves, through the nodosal plexus to the jugular ganglion, and directly to the petrous ganglion.

It may be well to describe each ganglion with its roots of origin, and its branches of distribution, in order to obtain a clear insight into the composition of the ganglionated cephalic plexus. Whereas the three roots will be described in the terminology of gross anatomy, it is realized that in their microscopic construction the roots of the sympathetic portions of the jugular, petrous and geniculate ganglia especially, may be of varying significance. Very few fibers of the sensory root of a sympathetic ganglion actually terminate within the ganglion, about its cells, and probably none except the few which terminate in its capsule, and in which arise general sensations from the ganglion to the central system. A motor root of a sympathetic ganglion may consist of two varieties of fibers; those which arise in the motor nuclei (of origin) in the central system and terminate about cells within the sympathetic ganglion (splanchnic efferent fibers) and, second, those which have the same origin and pass through the ganglion uninterrupted to their termination upon striated muscle (somatic efferent fibers), or pass through and go as splanchnic efferent fibers to other sympathetic ganglia. A sympathetic root of a ganglion may consist of two or even three varieties of fibers: (1) those which arise from cells in other sympathetic ganglia and terminate about cells in the ganglion in question, which cells in turn contribute fibers to its branches of distribution; (2) fibers arising in other sympathetic ganglia which pass through the ganglion uninterrupted, and out with its branches of distribution; and (3), in case of the mixed ganglia of cephalic and spinal nerves especially, fibers arising in sympathetic ganglia which enter the ganglion in question and terminate about cell bodies of the dorsal root ganglion type, that is, cell bodies giving origin to ordinary cerebro-spinal sensory fibers, which are thus enabled to carry into the central system sensory impulses arising in the sympathetic distribution, as well as sensations arising in the cerebro-spinal peripheral terminations. The present knowledge of the minute construction of the ganglia of the ganglionated cephalic plexus and the origin of the fibers related to them in the plexus renders it impossible to use a terminology in describing them based upon their construction.

The jugular ganglion

This ganglion lies on the trunk of the vagus nerve in the jugular foramen. It receives its motor and sensory roots from the vagus nerve and its sympathetic root from the superior cervical sympathetic ganglion through the nodosal plexus immediately inferior to it.

Its chief nerve of distribution is the auricular branch of the vagus, or nerve of Arnold, which leaves the jugular ganglion in the jugular foramen. It receives a branch from the petrous ganglion, enters the mastoid canaliculus in which it receives a communication from the facial nerve or merely lies in contact with it as far as the stylomastoid foramen, where it leaves the temporal bone. It may pass through the tympanomastoid fissure, after which it divides behind the pinna into two branches, one of which joins the posterior auricular branch of the facial, and the other ramifies in the posterior inferior part of the cartilaginous portion of the ear, and to the skin of the dorsal part of the pinna. It also supplies twigs to the bony part of the external auditory meatus, and to the lower part of the outer surface of the tympanic membrane.

The petrous ganglion

This ganglion lies around the glossopharyngeal nerve in the lower part of the jugular foramen. The motor and sensory roots are derived from the vagus and probably also from the facial and glossopharyngeal nerves. The sympathetic root is a fine filament derived from the superior cervical sympathetic ganglion.

The branches of distribution of the petrous ganglion are mainly through the tympanic branch, or nerve of Jacobson, to the tympanic plexus where communication is established with the facial nerve, and with two branches of the carotid nerve, the superior and inferior caroticotympanic nerves which enter the tympanic cavity through channels of the same name. From this plexus arises the small superficial petrosal nerve which goes to the otic ganglion. Other branches are distributed to the middle ear, and many filaments pass to the carotid plexus, while still others go to the pharyngeal plexus. Fibers also pass by way of the glossopharyngeal nerve to the tonsils.

The tympanic plexus serves as a common point of distribution of fibers from the carotid plexus, the cavernous plexus, and the superior cervical sympathetic ganglion, by way of the caroticotympanic nerves, and the jugular and tympanic nerves. The tympanic plexus communicates with the petrous, jugular, geniculate, otic and sphenopalatine ganglia, and the only cephalic ganglia of the sympathetic that it does not communicate with are the ciliary and submaxillary ganglia, which are supplied from the carotid plexus direct, or from plexuses derived from the carotid. The tympanic plexus is formed by nerves derived indirectly from the superior cervical sympathetic ganglion, the inferior caroticotympanic from the carotid plexus, the superior caroticotympanic from the cavernous plexus, and the tympanic nerve derived from the petrous and jugular ganglia which it has entered as the jugular nerve. The tympanic plexus communicates with the geniculate ganglion through a small branch which may be called the geniculotympanic ramus; it communicates with the sphenopalatine ganglion through the great superficial petrosal nerve by way of a branch that may be called the tympanopetrosal ramus; and it communicates with the otic ganglion by way of the small superficial petrosal nerve. It will be seen that the tympanic plexus with the carotid and derivitive plexuses and the cephalic ganglia enumerated above represent broken up cephalic portions of the gangliated sympathetic cord whose ganglia have fused more or less in the neck and have become scattered in the head. The tympanic plexus is the communicating plexus of the ganglia, and represents not only the rami communicantes, but the sympathetic trunks connecting the sympathetic ganglia. The ganglia of the glossopalatine, glossopharyngeal and pneumogastric nerves, that is, the geniculate, petrous and jugular ganglia, are different from the other cephalic sympathetic ganglia, in that the central and sympathetic portions have not become separated by the wandering off of the sympathetic portions. The ciliary, sphenopalatine, otic and submaxillary ganglia wandered off from the Gasserian ganglion at an early embryonic period, in a manner similar to the wandering of the sympathetic ganglia of the gangliated cord from the spinal root ganglia, and the four ganglia are true sympathetic ganglia. The sympathetic portions of the ganglia of the glossopalatine, glossopharyngeal and pneumogastric nerves remain fused with the spinal portions of the same ganglia, but the tympanic plexus forms a common ground of communication, and affords a ready means of understanding the relationship between all the cephalic sympathetic ganglia.

The geniculate ganglion

This ganglion lies embedded in the anterior border of the geniculum of the facial nerve dorsal to the hiatus Fallopii. Its motor root is of fibers from the facial nerve joining it at the great bend of the latter. The sensory root is derived from the dorsal root portion or the ganglion of the glossopalatine nerve, either in the ganglion or adjacent to it. The sympathetic root is the external superficial petrosal which passes through the hiatus Fallopii and connects the ganglion with the sympathetic plexus on the middle meningeal artery or through the great superficial petrosal nerve from the sphenopalatine ganglion. The branches of distribution of this ganglion pass through other ganglia, or other nerves. The great superficial petrosal nerve passes directly from the geniculate ganglion to the sphenopalatine ganglion. A communicating branch passes from the geniculate ganglion to the small superficial petrosal nerve which afterwards enters the otic ganglion.

The sphenopalatine or Meckel's ganglion

This ganglion and the three following may be described as in the anatomy of Morris, remembering to dissociate them from the trigeminal nerve. The important facts concerning these ganglia are to determine their motor, sensory and sympathetic roots of origin, and to establish their fibers of distribution. The three roots of origin, motor, sensory and sympathetic, of the sphenopalatine ganglion are from the facial, trigeminal, and great deep petrosal nerves respectively. The fibers are distributed to the mucous membranes lining the ethmoidal and sphenoidal sinuses, and that of the nasal, buccal and pharyngeal cavities. Fibers of taste belonging to the glossopalatine nerve, arising from the geniculate ganglion, pass through the sphenopalatine ganglion from the great superficial petrosal nerve, and are distributed to the soft palate. Some of the small palatal muscles may be supplied by motor branches passing through this ganglion without interruption.

The position of the sphenopalatine ganglion is determined by the size and shape of the sphenoid sinus. In many recent dissections I have found it medial, lateral or inferior to this sinus and in five subjects the Vidian nerve passed through the sphenoid sinus in a tube of bone covered with mucous membrane.

The otic ganglion

The motor root of the otic ganglion is derived from the motor nucleus of the facial and some fibers probably also from the masticator nerve. Its sensory root passes through it from the glossopharyngeal nerve, and its sympathetic root from the middle meningeal plexus and from the tympanic plexus through the continuation of the tympanic nerve in the small superficial petrosal nerve. The sympathetic fibers from the otic ganglion are distributed to the parotid gland, the glands and vessels of the tongue, and uninterrupted motor cranial fibers to the tensor tympani and tensor veli palatini muscles.

The submaxillary ganglion

The motor root of this ganglion is derived from the motor nucleus of the glossopalatine, the sensory root from the lingual (Gasserian ganglion) and the sympathetic root from the plexus on the facial artery, or from the sympathetic portion of the geniculate ganglion through the chorda tympani. The fibers arising from this ganglion are distributed to the submaxillary and sublingual glands and to the floor of the mouth.

The ciliary ganglion

The motor root of this ganglion is derived from the oculomotor nerve, fibers which terminate in it, the sensory from the trigeminal, and the sympathetic root from the cavernous plexus. The fibers from this ganglion are distributed to the ciliary body, the iris, the cornea, and probably to the lachrymal gland.

The parotid ganglion

A small plexiform mass containing ganglion cells, and located beneath the parotid gland on the auriculo-temporal nerve, connecting with the vagus, facial and trigeminal nerves, has been dissected repeatedly by students in the laboratory at Tulane University under my direction. At present investigations are under way to determine if this is the ganglion of the parotid gland. I realize that the term sympathetic needs restriction in its use, therefore, I propose that it be reserved for use in gross description, the sympathetic nervous system as a whole, in the same way that the terms central and peripheral nervous systems are used. In any presentation of the functional differences of neurones the terms somatic motor, somatic sensory, visceral motor and visceral sensory should be used insofar as present knowledge of the subject will permit.

From the standpoint of gross anatomy there can be no question as to the propriety of assembling the ganglia of the head and their connections as the ganglionated cephalic plexus, and from the standpoint of their sympathetic connections they are one, although it is desirable to determine exactly what fibers are motor, sensory or secretory, where they have their origin and where they are distributed.

ANATOMY IN THE FAR EAST

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THREE FIGURES

CHINA

Of all branches of western education which are striving to enter China modern anatomy and pathology will be among the last to gain admission. Dissection and autopsy on the human subject are directly opposed to all the ancient culture of China, and for this culture, which has endured for so many centuries, China has decidedly more respect than for that of the West. Western education although admitted to be more practical is scarcely considered culture by the Chinese. However, should the present form of government obtain, the outlook for anatomy may rapidly improve, for the medical missionaries and the Chinese educated abroad, many of them in medicine in America, have been most directly responsible for the "awakening of China," the recent revolution, and the growing popularity of western education.

Up to the present time a religious respect for custom and tradition, the worship of ancestry, and the great fear of arousing public disapproval have made the teaching of anatomy and pathology in the medical schools of China all but impossible. Autopsies on natives are not permitted in China and the dissection of a Chinaman, particularly by a foreigner, would be sufficient grounds for a riot. These, among many others, are the difficulties, more or less variable, which each medical school of China encounters; for as yet medical education is tolerated rather than encouraged. Several of the medical schools, however, are making a commendable effort to overcome this deficiency of the field of anatomy, either by a liberal use of models and manikins and dissection on dogs, as at the Union Medical College in Peking or by a more extensive course in comparative anatomy followed by a study room course in human anatomy with models and lectures as at Nanking University. Other schools have tried to obtain human dissection material from the Philippines, but we were unable to supply them.

The medical schools of China, of which there are now some seventeen, are comparable to the smaller proprietary medical schools of the United States of a generation or two ago. All but one have been established to forward missionary work. Some teach in English, some in Mandarin, some in Chinese, and one in German. Microscopic anatomy fares better than dissection. Several schools have fair laboratories and equipment for histology and embryology.

In China where there is so much superstition concerning the human body—a superstition many of the Chinese physicians seem never thoroughly to overcome for themselves—the teaching of dissection should be a most desirable and practical measure in medical education. A glimpse of what is inside the natural human being would, no doubt, tend to allay much of this superstition and give the student more confidence in the foreigner's later instruction.

The Chinese being a practical people—they learned centuries ago by experience that it is not safe to drink unboiled water in their country—they will probably eventually countenance, then approve, dissection and autopsies. Yet this time is, no doubt, a long way off. The physician, at least in North China, does not enjoy a good social standing, and the medical students as a rule are recruited from the lower levels. Why should the Chinaman throw his sacred traditions to the wind and permit the mutilation of a Celestial's body by a foreigner all because the foreigner (as yet a not altogether popular person) tells him such will make it easier to apply the western art, in which the Chinaman himself has little confidence? The attitude of the more enlightened public is, as a rule, such as this and frequently one of a pronounced suspicion.

Hongkong

The British colony of Hongkong, although essentially a Chinese city, has succeeded in making dissection and autopsies on the human subject available to her Chinese students. The Medical School here is a part of the Hongkong University. Dissection and autopsies form a conspicuous part of the five-year curriculum of this school. It is here also that we get the best idea of the Chinese student as a student of anatomy. During the short time these courses have been open to him, he has shown himself, up to a certain point, a good student, a good dissector and neat with his drawings. I am told further that, as might be expected from the old system of education so long in vogue in China, he shows a great tendency to drift into learning anatomy from the book by memory. As to his interest in the subject, it seems difficult to gage the Chinese student. The whole thing, methods as well as subjects, is so new to his countrymen that we would expect him to take much of it on faith, some by curiosity and perhaps more by discipline.

INDO-CHINA

In French Indo-China there is one Medical School with a hospital in which the natives are given courses in medicine. This is the "Medical School of French Indo-China" at Hanoi. It was established by the French and is a government-supported school. The faculty consists of army surgeons and sanitary physicians of the colonial government. France's colonies in the Far East are considered by her as permanent dependencies and thus little effort is made to place higher education within reach of the native. The primary object of the school is, I was told, to train high class hospital assistants, quarantine assistants, sanitary inspectors, and the like, to fill minor positions in the government service, which would be too expensive to have filled by Europeans. It is rare to find a native graduate in practice for himself. Anatomy being of little direct practical value, the courses here, although modelled after those of the universities in France, are much more abbreviated than the course of the latter schools. Anatomy is a means to an end and as such is likely to remain, and, indeed, there seems little reason for change.

JAPAN

The medical schools of Japan are departments of her universities. The College of Medicine of the universities of Tokyo and Kyoto are the best examples. Both of these institutions possess rather well equipped laboratories of anatomy, pathology and bacteriology, physiology and chemistry, and a medical faculty nearly all of whom have received training in the universities of Europe or America. The instruction is in Japanese, but a reading knowledge of German is required of all matriculates. The medical schools were established about twenty-five years ago along with the organization of the universities. At this time the faculty consisted almost entirely of foreigners, as was the case with the other branches of the university. The Japanese, however, have shown a remarkable adaptability to western medical education and have been rapidly replacing the foreign professors by Japanese. The latter are trained entirely abroad, or, having taken the M.D. degree in Japan, are later sent abroad for specialization. This is especially true of the anatomy faculty, for as yet little attempt seems to be made to train anatomists at home.

The courses in anatomy, so far as I could gather, are conducted after modern ideas and rather according to the German method. The department, however, is not an institute of the university but rather a preparatory school for clinical medicine. There also exists in Japan a prejudice against the too free use of the human subject by the anatomist or the pathologist.

THE PHILIPPINES

Modern anatomy in the Philippines, or we might say in the Orient, dates only from the opening of the Philippine Medical School (now College of Medicine and Surgery, University of the Philippines) some six years ago.

Fostered by the Bureau of Science of Manila and by a "Board of Control" acquainted with and in sympathy with research work and in a city where health problems were being worked out almost weekly, it is easy to understand the high ideals and liberal financial backing with which this school began its work. Modelled after the better American medical schools and supported by a liberal appropriation from the Philippine government, the school has always been able to maintain in the biologic branches teachers giving their entire time to the separate departments. Time, funds, technical assistants and opportunity have been and are afforded each man in each department for scientific investigation. Anatomy has enjoyed these luxuries almost equally with the other branches.

The Department of Anatomy of the College of Medicine and Surgery, University of the Philippines, gives courses in gross human anatomy, elementary neurology, histology and embryology. The Laboratory for Histology and Embryology occupies the second floor of the east wing (50 x 80 feet) of the new Medical School building. Here are located two offices for members of the staff, a private laboratory and preparation room and the class laboratory. The floors are of concrete. Each room is fitted with built-in hardwood tables and side desks, fully equipped with lockers and supplied with running water, gas, sinks and electric lights. Nearly the whole north side of this wing is window space. With the exception of a few rainy days, any part of the laboratory is light enough for high-power observation with the microscope. Each student is supplied from the central store room with a microscope, instruments, and so forth, for the course, and is given individual desk and locker space.

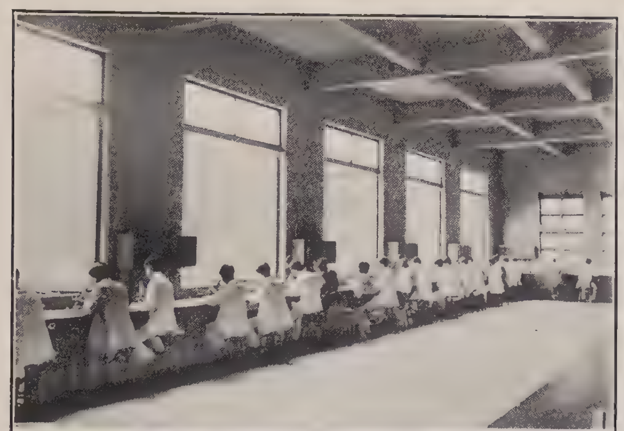
The entire third floor of this building is also given over to anatomy. Here are located two dissecting rooms, a study room with models, a laboratory for elementary neurology and the study of cross sections, an instructor's room, a preparator's and specimen store-room, a lavatory and a large corridor with student's lockers. On the ground floor in the city morgue are located the cadaver vats. Here the subjects are kept in the refrigerator boxes till embalmed. The morgue is connected with the dissecting room through the medium of a hand power lift upon which cadavers are hoisted to the laboratory. For dissecting tables plain heavy wood tables covered with a sheet of galvanized iron or tin are employed. The building being of reinforced concrete, everything can be washed easily. Figure 2 gives an interior view of the dissection laboratory.

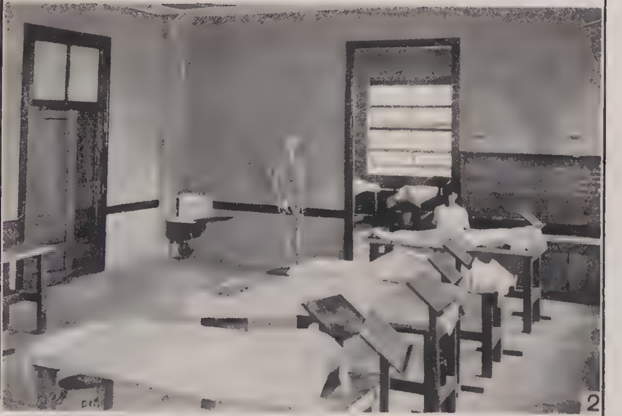
The Department is in charge of myself and Ruskin M. Lhamon. For additional assistance in microscopic anatomy we have been favored by the loan of an officer from the medical corps of the United States Army. During the past year we have been fortunate in securing the services of Dr. Ernest R. Gentry in this capacity. The Department of Zoology of this university has rendered us valuable assistance in the laboratory course in embryology. While during the past two years the Department has had demonstrators in gross anatomy, there are as yet no permanent occupants for these positions. Student demonstrators have not proven desirable. With this arrangement, Dr. Lhamon and I have enjoyed a fair amount of time for investigation. Filipino 'boys,' after a long and tedious period of training, make excellent and faithful technical assistants.

Courses of instruction

The courses of instruction follow the same general plan as that of the more advanced medical schools of America. Special effort is, moreover, made to place the subject in hand in a more simple form before the students. The proximity of the morgue makes it possible to secure at practically all times fresh tissue for the class in microscopic anatomy. The rainy season compels us to postpone practical instruction in section cutting, staining, and so forth, till the latter part of the first year. The relative uniformity of the seasons' temperature places continuously much ready embryologic laboratory material near our doors. In the laboratory courses in elementary neurology dissection of the human brain follows laboratory instruction in comparative neurology and the development of the central nervous system, and is succeeded by first hand study of the fiber tracts and of the microscopic structure of the central nervous system and organs of special sense.

In gross human anatomy we have made one departure which can be recommended to those laboratories with a limited teach-





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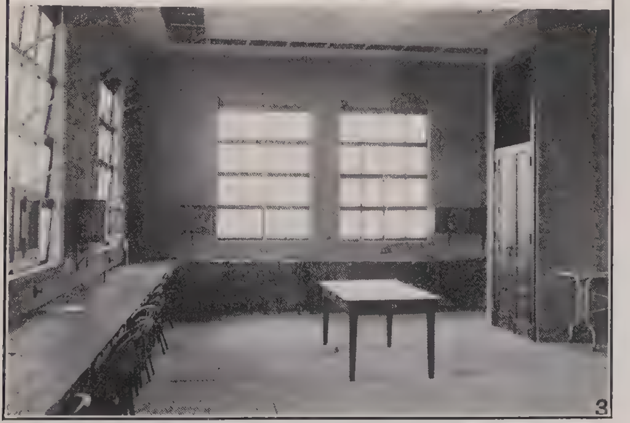

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Fig. 1 Interior view of the class laboratory of microscopic anatomy.

Fig. 2 The dissection laboratory.

Fig. 3 Laboratory for elementary neurology and study room for cross sections and special dissections.

ing staff and an abundance of material, as is the case here. All of the first year class are put to work upon the same dissection (two separate dissections in large classes) and continued in such sections so nearly as possible throughout the course. During the first dissection they are working upon the same cadavers as the second year students or with such of the latter as have failed to finish their dissection in the first year. Study room specimens of the lower extremity are available for comparison when they are working upon the upper extremity and vice versa. The more brilliant students are encouraged to do special dissections, such as that of the lymphatics, variations, and so forth. Lectures in gross anatomy are quite unsuited for our students and we are beginning to be a little skeptical of the laboratory manual. Where, as here, it is all-important to develop in the students individual initiative (a quality forcibly discouraged here for the past three hundred years) for a practice in later life under the most trying conditions, anatomy can be made of the highest practical value if the student can be led to approach it with the attitude of a well guided explorer rather than that of a well booked tourist on the beaten path. We, however, have found that this method entails more time and personal instruction on the part of the instructor.

The Filipino student

A profound respect for western civilization and American educational methods is responsible for a keen desire upon the part of the student to catch every word of instruction and to remember it literally.

The students are practically all conscientious, hard workers and make good use of their text-books and are clever at dissection. They will undertake any amount of work assigned to them but will not volunteer for any work not required and will not remain during vacation for work in the laboratories or the hospital without pay. They prefer American instructors and will submit without murmur to any schedule or discipline arranged by these, but often resent the same from the junior men of their own nationality. It is very common to find in the first year class, students who can give a complete description (sounding very much like the text-books or one's own lecture) of the structure of the kidney and the next moment pronounce a section of the kidney to be tongue. The dissections of the right side are better than those of the left, the illustrations in the atlases being from the right side.

A student in anatomy made a dissection of the peripheral lymphatics which was worthy of a text-book figure, but when examinations came on, a few days before the work could have been finished, he lost interest in the dissection and left it lying upon the table in our tropical heat to perish.

Yet some surprises in originality are in store for the instructor who has found the Filipino lacking in this quality. To my first class in gross anatomy in Manila I was demonstrating the elasticity of the arteries and explaining the change during old age, not troubling them with any pathological names, when one of the students called my attention to a calcified radial artery in an eighty-year-old subject. On showing this to our one Igorote student (from a mountain tribe which do not wear trousers) who had never been inside of a hospital, he immediately exclaimed, "Ah! Arteriosclerosis, my father died of that."

Manila, February 28, 1913.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE, NO. 237.

NOTES ON RÖNTGEN-RAY INJECTION MASSES

G. H. PARKER

In studying variations in the circulatory systems of animals, it is often convenient to be able to make a rapid preliminary inspection of the preserved material on the basis of which a selection of specimens for detailed dissection can be made. Such an end can be accomplished by using an injection mass which is so compounded as to be opaque enough to admit of the preliminary inspection by Röntgen rays and firm enough to make subsequent dissection easy. The following four masses have been found to meet these requirements for small animals.

No. 1. This mass is a simple gelatin mass containing in suspension a sufficient quantity of bismuth subnitrate to make it opaque to the Röntgen rays. The proportions of the ingredients are as follows:

Dry gelatin	2.5 grams
Water	100.0 cc.
Bismuth subnitrate	25.0 grams

The gelatin is to be dissolved in the water, which should be warm, and to this solution the bismuth subnitrate is to be added. It is well to strain the mass through cheese cloth. If the mass is to be kept in stock for any length of time, a small amount of thymol or other bactericide should be added. The mass should be injected warm enough to be fluid. It flows with great freedom and yields a very complete injection. Its whiteness is usually sufficiently distinctive, but it may be colored, like ordinary white starch-mass, with carmine, Prussian blue, etc. Its chief deficiency is its tendency to separate, the heavy bismuth subnitrate settling on the lower inner surfaces of the vessels. It must, therefore, be thoroughly agitated before it is injected and radiographs are usually more successful if taken shortly after the injection has been made than after the specimen is a week or so old. The mass yields very sharp radiographs and is satisfactory for subsequent dissection. The specimens should be preserved in alcohol.

No. 2. A second bismuth mass was made from vaseline or petrolatum to which was added enough bismuth subnitrate to render it reasonably stiff. The proportions were as follows:

Bismuth subnitrate	20 grams
Vaseline	130 grams

The two ingredients are to be mixed with a spatula on a glass plate. It is well to strain the mass by pressing it through cheese cloth. It can be injected cold, though the injections are fuller if the specimen is slightly warmed previous to the introduction of the mass. The bismuth does not tend to separate in this mass as in the gelatin mass. The radiographs are sharp. This mass, like No. 1, may be variously colored.

No. 3. The third mass was compounded on the same plan as No. 2 except that lead chromate was used in place of bismuth subnitrate. The proportions of the ingredients were as follows:

Lead chromate	20 grams
Vaseline	100 grams

This mass is, of course, yellow in color; otherwise it is much the same as No. 2. In many respects it resembles the red-lead mass described by Descomps, de Falletans, et de Lalaubie ('10).

No. 4. Mercury was naturally among the first substances to be used for Röntgen-ray injections. Haschek und Lindenthal in 1896 published a radiograph of the human hand injected with Teichmann's mass the opacity of which depended in part on the contained chalk but chiefly on the cinnabar. In the matter of opaqueness the great advantage of metallic mercury over its salts was clearly shown by Braus ('96). Anyone, however, who has used fluid mercury for injection must have been impressed with its many inconveniences: on handling the preparation, the mercury is very likely to shift about in the vessels and spaces, and, if a slight rupture is made, the whole injection may be lost.

To obviate these difficulties and yet retain the advantages of the metallic mercury, the suggestion of Fredet ('00) to use mercurial ointment was adopted. An injection mass compounded of mercurial ointment and vaseline proved most satisfactory. For a freely flowing mass the following proportions were used:

Mercurial ointment	50 grams
Vaseline	50 grams

The mercurial ointment, composed of one part by weight of metallic mercury and one part by weight of lard, is thoroughly mixed with an equal weight of vaseline, strained, and injected cold or slightly warmed. The mass itself is dark gray in tone but may be colored by any of the ordinary means. It flows freely, especially if the part to be injected is previously warmed, gives a very sharp radiograph, and from its oily nature, can be easily wiped from the specimen, if, by accident, it overflows. On the whole, it is a most satisfactory injection mass for Röntgen-ray work.

BIBLIOGRAPHY

Braus, H. 1896 Ueber Photogramme von Metallinjectionen mittelst Röntgen-Strahlen. Anat. Anz., Bd. 11, pp. 625–629, Taf. 1.

Descomps, P., de Falletans, G., et de Lalaubie, G. 1910 Technique pratique pour injections et radiographies de pieces anatomiques. Bull. et Mem. Soc. anat., Paris, ann. 85, pp. 493–496.

Fredet, P. 1900 Les artères de l'utérus étudiées au moyen de la radiographie. Compt. rend. 13 Congrès internat. med., Paris, sect. anat., pp. 103–108.

Haschek, E., und Lindenthal, O. T. 1896 Ein Beitrag zur praktischen Verwertung der Photographie nach Röntgen. Wiener klin. Wochenschr., Jahrg. 9, pp. 63–64.

BOOKS RECEIVED

THE FIRST SIGNS OF INSANITY, Their prevention and treatment, Bernard Hollander, M.D., 346 pages including index, 1913. $3.25, net. Funk and Wagnalls Company, New York and London.

COLLECTED PAPERS FROM THE RESEARCH LABORATORY PARKE, DAVIS AND COMPANY, DETROIT, MICHIGAN, illustrated, 287 pages including index, 1913, reprints, volume 1.

A METHOD OF ELECTROPLATING WAX RECONSTRUCTIONS[1]

IVAN E. WALLIN

The temporary nature of wax models has been a matter of some concern to investigators using the Born method of reconstruction. From a casual examination of the literature I have not found any methods described for making wax models permanent. Paints and varnish have been used with a certain degree of success. Small models when coated with French varnish will not wilt as readily as an uncoated one, the fragility however, is not altered by this process.

In technical literature I found a method for electroplating on wax and other non-metals with the use of graphite. This method was tried but the results were far from satisfactory. I experimented with graphite and bronze powder and finally devised a method which gives good results.

Electric current. In larger cities laboratories are often supplied with the direct current. This is generally a 110-volt current and appears to be just the proper current for this kind of electroplating. An Edison storage cell may be used if the direct current is not at hand. To get the proper amperage a lamp rheostat which is easily made (see any text book on electricity) is very convenient. The lamps are arranged in parallel. One 16-candle-power lamp gives approximately one-half ampere, two lamps one ampere, and so forth. The number of amperes to be used will depend upon the size of the object to be plated. A model the size of an ordinary drinking glass will be plated satisfactorily with one-half ampere.

Bath. The copper sulphate solution which I have used has the following composition:

$CuSO_4$	150 grams
H_2SO_4	50 cc.
Distilled water	1 liter

Dissolve the copper sulphate in the water, then add the sulphuric acid. The size of the bath will depend upon the size of the object to be plated. There should be a space of at least six inches between the model and the sides, bottom, and top of the vessel containing the fluid to obtain the best results. For the anode a copper plate may be used. This should be large enough to form a lining to the inside of the vessel.

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[1] From the Anatomical Laboratory, University and Bellevue Hospital Medical College, New York City.

Preparation of model. First coat the model with graphite (Dixon's flake graphite. No. 2). This may be applied with the fingers. In places which can not be reached with the fingers use a small bristle brush. Next make a paint or suspension mixture of bronze or copper powder in chloroform. With a camel's hair brush paint the graphite coated model with the bronze paint. One should not rub over a spot more than once or twice as the chloroform dissolves the wax. It will require a couple of hours or more for this coat to dry. When it is thoroughly dry the bronze will not rub off and the model should again be coated with graphite, using the same method as in the first coat. If the bronze coat is not even it may be touched up with the bronze paint before the last coat of graphite is put on. Heat a copper wire (preferably an insulated wire, removing about an inch-and-a-half of the insulation from the two ends) and plunge it into the wax, holding it in position until it has cooled and remains firm. For a large model it is advantageous to use a number of wires distributed over the model. At the point where the wire comes into contact with the model the wax should be scraped from the wire. With the point of a knife pack graphite around the wire to insure a good contact between the wire and the coating on the model.

Wax being lighter than the fluid of the bath it is necessary to anchor the model. This may be done in two ways, either by attaching a weight to the wiring or plunge a hot wire hook into the model and attach the weight to the hook. If the weight is metal it should be coated with paraffin.

To determine the polarity of the electric current attach one of the wires to the copper plate and hold the other in the fluid of the bath for a few moments. Copper will deposit on the cathode which is to be connected with the model. When the model is ready to be plated it should be placed in the bath and if it contains cavities it should be turned so that all the air will escape. The current should not be on when the model is being lowered into the bath for the heat generated will melt the wax and insulate the wire attachments from the coating.

After the model is fairly plated over there may be a few spots which have not received a deposit of the copper. Apply the bronze paint to these spots and then graphite and immerse in the bath again.

The thickness of the plating will depend upon the length of time in the bath. To render a model durable it should have a fairly thick coat of copper (from 0.3 mm. to 0.8 mm.). The necessary time required for this thickness will depend upon the size of the model and the amperage and can only be determined by experience.

After the plating is completed, the model should be washed thoroughly in water, then in alcohol, and dried rapidly by fanning. When drying slowly from a washing in water the color of the copper may not be constant.

I wish to take this opportunity to thank Prof. S. A. Tucker of Columbia University, who so kindly gave me the use of his laboratory and apparatus when I first began this work and also for valuable information in connection with electroplating.

OBSERVATIONS ON THE PERIPHERAL DISTRIBUTION OF THE NERVUS TERMINALIS IN MAMMALIA

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THREE FIGURES

The occurrence and relations of the nervus terminalis in various types of vertebrates has in recent years been the subject of a relatively large number of contributions, appearing in the main from American laboratories. Johnston in a recent communication summarized this literature in tabular form, and to this the reader is referred for a general consideration. From a study of this literature and from his own contributions, Johnston concludes that, "In all the forms in which the nerve enters the olfactory bulb it as been shown that its fibers pierce the formatio olfactoria to pass on to their proper endings in some part of the forebrain," and further, that the facts appear to show "that the nervus terminalis in most fishes and amphibians is a ganglionated nerve whose root enters the forebrain caudal to the olfactory bulb, usually near the site of the embryonic neuropore, and whose fibers are distributed to the wall of the nasal sac." In this paper Johnston notes the presence, and gives a general description of the nervus terminalis as observed in reptilian and mammalian embryos, his study including among the latter, pig, sheep and human embryos. His investigation show that in reptilian and mammalian embryos this nerve, "enters the brain at a point somewhat removed from the median plane but otherwise holding the same relation to the primordium hippocampi, precommisural body and neuroporic recess which the root holds in selachians." The fibers are said to arise from bipolar ganglion cells, collected into a compact ganglion terminale in the pig and human embryos

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and into several clumps in the course of the nerve and its branches in turtle embryos. So far as concerns the peripheral distribution of the nervus terminalis in mammalia he notes that, "In the pig the nervus terminalis is clearly distributed to the vomeronasal organ," and, "In man the fibers mingle with the olfactory strands of the nasal septum." McCotter has called attention to the presence of a nervus terminalis and a gânglion terminale in adult dogs and cats. These results were obtained in the main by gross dissection, controlled by sections and tissue membranes, spread and stained to admit of study under the microscope. The nervus terminalis was traced to its entrance to the forebrain in both the dog and the cat, ganglion cells were noted in its intracranial course as also small collections of ganglion cells in the septal portion of the vomeronasal nerve just dorsal to the vomeronasal organ. McCotter concludes, "that there is normally present in the adult dog and cat a ganglionated nerve connected with the vomeronasal nerves on the one hand and apparently with the forebrain on the other, having thereby the same morphological relations in these mammals as is described for the nervus terminalis in the lower forms."

Johnston's recent studies, above referred to, and as noted in his communication, were made in part on series of embryos in this laboratory. Our interest in the presence of the nervus terminalis in mammalian embryos having thus been stimulated we were pleased to note a differential staining of this nerve in a series of sagittal sections of the heads of two rabbit embryos, which from size and general development were estimated as having been removed about a week before birth. These heads had been stained after the pyridine-silver method as used by Ranson, with certain modifications to be noted. Our observations on the peripheral distribution of the nervus terminalis in mammalia pertain, therefore, to the rabbit.

Method. The essential steps in the Ranson pyridine-silver technic are as follows: Fixation in ammoniated absolute alcohol; thorough pyridine penetration; thorough washing in distilled water; impregnation with a 2 per cent silver nitrate solution; reduction of the silver by means of a formalin-pyrogallic acid solution. Early in our use of this method we became aware of very evident shrinkage of the nerve cells, probably due to the ammoniated alcohol fixation. This was largely obviated by the injection of the ammoniated alcohol solution into the fresh tissues. The investigations undertaken demanded that the method be made applicable to decalcified tissues. It was found that this could be done by using nitric acid as a decalcifier.

The method as now used in this laboratory is as follows: The animal is prepared by chloroform anesthesia and the heart incised before it ceases to beat. This to obtain as complete drainage of the vascular system as is possible. A cannula is then inserted into the main artery supplying the area containing the nervous tissues to be subjected to silver staining and the cannula filled with normal salt solution. By clamping branches the area to be injected can be restricted. A solution consisting of 95 per cent alcohol and a 1 per cent concentrated ammonia is then rapidly injected under a pressure of from 5 to 10 pounds, this being continued until the parts seem well injected. The ganglia, nerve trunks, pieces of the central nervous system, as desired, are then removed and placed in a similar ammoniated alcohol solution, in which they remain for from two to three days. The further treatment is as is given by Ranson for the pyridine-silver method. This method of fixation by a preliminary injection of the ammoniated alcohol solution seems to us to present distinct advantages, especially when used in the study of ganglia and peripheral nerves. For instance, the shrinkage and distortion of the peripheral layers of cells of sensory ganglia is largely obviated. The elements are well fixed and are slightly separated so that much thicker sections may be cut and studied to advantage. The impregnation and reduction of the silver seems more uniform and more certain.

The pyridine-silver method as adapted so as to include decalcification of the tissues is as follows:

1. Adult or young animals and embryos of sufficient size to admit of injection are injected with ammoniated alcohol solution, as above described, and the tissues placed in the ammoniated alcohol for from two to four days, depending on the size of the tissue mass to be fixed.
2. Transfer to distilled water, in which the pieces remain until they sink.
3. The pieces are then transferred to a 7 per cent solution of nitric acid, made with distilled water, in which they remain until the decalcification is complete; which varies with the age and size of the tissue block.
4. Wash in distilled water for about one-half hour, the water being changed frequently.
5. The pieces are then transferred to alcohols of 80, 90 and 95 per cent, to each of which is added 1 per cent of concentrated ammonia. A thorough treatment with ammoniated alcohol at this step seems to us essential; three to eight days, depending on the size of the pieces.
6. Rinse in distilled water and place for twenty-four hours in pyridine.

7. Wash thoroughly in distilled water for twenty-four hours, the water being frequently changed. As the immediate transference of the tissues from the pyridine to the distilled water is liable to result in a swelling of the tissues, which may lead to a bursting of the hemispheres, a gradual transference from the pyridine to the distilled water is recommended.

8. Transfer to a 2 per cent solution of silver nitrate in distilled water, in which the tissues remain for from three to five days, in the dark and at a temperature of about 35°C.

9. Rinse in distilled water and place for from one to two days in a 4 per cent solution of pyrogallic acid in 5 per cent formalin.

10. Dehydrate thoroughly, beginning with 80 per cent alcohol. Aceton may be used to hasten the dehydration, but should be preceded and followed by alcohol. Clear in xylol and embed in paraffin. A necessary stay in the warm oven, even to forty-eight hours, to insure thorough paraffin penetration, does not seem to affect the stain.

The possibility of decalcification combined with preliminary ammoniated alcohol injection greatly extends the applicability of the pyridine-silver method. We have found it possible to stain half of the head of a six day rabbit, head and neck of a medium sized frog, head of a small turtle, and so forth. After the injection with the ammoniated alcohol we have removed the skin and exposed the brain. Further cutting of the pieces was delayed until after the decalcification and second ammoniated alcohol treatment. The paraffin sections may be cut serially, and fixed to the slide by the water albumen method in the usual way.

We are able to confirm Ranson's statement, and find it applicable to the method as here modified, namely, "With fresh pure chemicals, absolutely clean utensils, and a reasonably constant temperature this method can be relied upon to give uniform results."

Material. The material on which our observations on the peripheral distribution of the nervus terminalis in mammalia is based, consists of series of sections of heads of rabbit embryos and young rabbits, cut in the sagittal plane, as follows: *a*, rabbit embryos, 3 cm. head-breech length; *b*, rabbit embryos removed about one week before birth; *c*, young rabbits one day old; *d*, young rabbit six days old. For the two younger stages the entire head was cut, for the older stages a little over one-half of the head, the series beginning about 2 mm. to the left of the mid sagittal plane, thus including the nasal septum and the entire left half of the brain and head. Two complete sagittal series of each of the three younger stages are at our disposal and one complete sagittal series of the oldest stage. In each of these series the fibers of the nervus terminalis, throughout their entire course, are stained deeply brown or black and are of relatively fine caliber, while the olfactory formation, and the olfactory nerves including the vomeronasal portion, are colored a light brown and are traced as large compact bundles with sheath cells rather than separate fibers. The differential staining is so distinct and characteristic that the two types of fibers can not well be confused.

Graphic reconstruction of the oral part of the forebrain, the olfactory bulb and nerves, the vomeronasal nerves and the nervus terminalis of the right side have been made for the three younger stages. Of the two younger stages by Guild, of the one day stage by the senior author, as well as a partial reconstruction of the six day stage. The resultant figures of the three stages completely reconstructed are so similar that a publication of all seemed unnecessary. The one day stage was chosen for the reason that the parts sketched were less compactly grouped and can thus be followed in the figure with greater ease. The graphic reconstructions were made with the aid of a camera lucida at a magnification of 75 diameters for the one day stage and 85 diameters for the two younger stages. Doubtful points were controlled under higher powers. By the use of orienting points selected in the sections, field after field was adjusted and the pertinent parts traced in pencil. In the final figure only nerve segments clearly joined were sketched in ink. The right side was chosen for the graphic reconstructions by reason of the fact that the final figures were somewhat easier to make in that in tracing the series, beginning with the nasal septum and proceeding lateralwards, the nervus terminalis was superimposed on the olfactory bulb and nerves. The distribution of this nerve on the left side is, it may be anticipated, the same as that on the right side. As concerns the graphic reconstruction reproduced, we desire to state that while the distribution of the nervus terminalis is, as we believe, correctly given, with the magnification used it was not possible to show in detail the size and number of the component nerve fibers of the several branches of the nerve. In order to make the figure intelligible we found it necessary to emphasize the branches of the nervus terminalis and sketch them as solid black lines and thus bring out disproportionately large certain of the finer branches and connections. The distribution of the ganglion cells as given is based on camera lucida projections. In the final drawing the ganglion cells, for the sake of clearness, are sketched disproportionately large. As stated above in all of our series the nervus terminalis was found differentially stained so that under the magnification used it was possible to distinguish between its branches and those of the olfactory and vomeronasal nerves.

Our observations on the superficial origin of the nervus terminalis in mammalia are in harmony with those of other authors who have dealt with this subject. In the rabbit the main portion of the nervus terminalis arises from the ventro-mesial surface of the forebrain; caudal to the olfactory bulb and stalk and oral to the lamina terminalis. Its origin is not by a single compact bundle and from a limited area, but rather by several smaller bundles or roots which pierce the brain substance rather gradually, in smaller subdivisions. In the two younger stages a smaller root was traced to its entrance in the forebrain, at a region more dorsally placed on the medial surface. In the one day stage this root could not be clearly traced to its entrance in the forebrain. The nervus terminalis passes forward along the ventro-mesial aspect of the olfactory bulb, in the form of a loose plexus consisting of three or four strands joined by anastomoses, to a position mesial to the region where the branches of the vomeronasal nerve unite to form a main strand, just above the cribriform area. In this intracranial portion of the nervus terminalis there are found here and there small groups of ganglion cells, either at nodal points of the plexus or as single cells or clusters of two or three ganglion cells along the course of the nerve filaments, and in all of our series there was observed a relatively larger mass of ganglion cells in the region where the nervus terminalis crosses the vomeronasal nerves. This latter mass we regard as the 'ganglion terminale' of authors. The origin, general course and relations to the olfactory bulb and vomeronasal nerves of the nervus terminalis of the rabbit may be seen in figure 1, which figure duplicates in all essentials the figures obtained by graphic reconstruction of this region for the two younger stages studied and for the six day stage. In its passage through the cribriform area the nervus terminalis accompanies in the main the vomeronasal branches, lying on their mesial aspect. If in our sagittal series of heads of embryos and young rabbits the study is begun with the nasal septum and carried from here to the right, it may be seen that the branches of the nervus terminalis are in the deeper portion of the septal mucosa and are first met with on the mesial surfaces of the vomeronasal branches, which pass mesially to the filaments of the olfactory nerves as they radiate to the different parts of the septum, thus in a deeper plane of the septal mucosa. In all of our series, terminalis branches are associated with each of the three main branches of the vomeronasal nerve and may be traced with them to their termination in the vomeronasal organ. Scattered along the course of the terminalis branches there are found smaller and larger groups

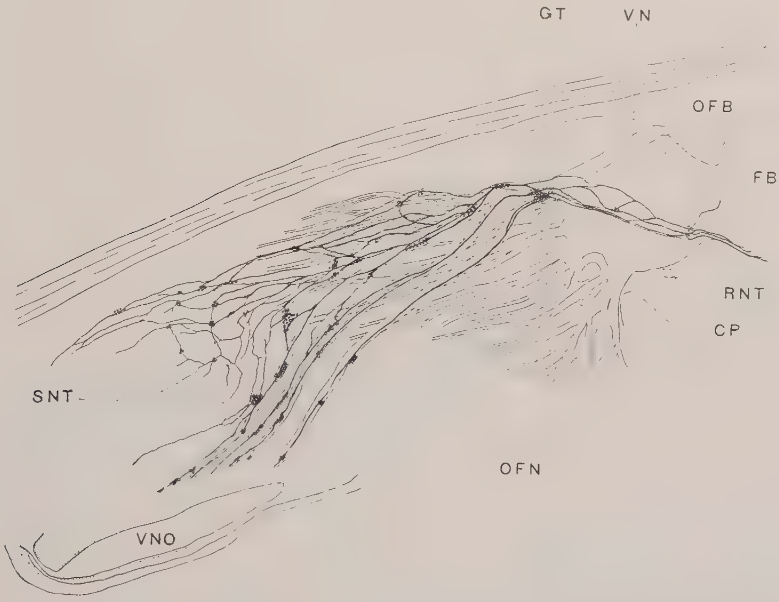

Fig. 1 Graphic reconstruction of right side of olfactory bulb and stalk, olfactory and vomeronasal nerve, and nervus terminalis, based on a sagittal series of sections of head of a one-day-old rabbit, stained after the pyridine-silver method, and showing differential staining of the nervus terminalis. The nervus terminalis is given throughout its course in jet black; the olfactory and vomeronasal nerves are given in outline; *fb*, forebrain; *ofb*, olfactory bulb; *vn*, vomeronasal nerve; *rnt*, roots of nervus terminalis; *gt*, ganglion terminale; *snt*, septal distribution of nervus terminalis; *cp*, cribriform plate; *vmo*, vomeronasal organ, given in outline. × 10.

of ganglion cells, even in connection with the end branches of the nervus terminalis found in the mucosa of the vomeronasal organ. Here and there there may be observed anastomosis between terminalis branches accompanying the vomeronasal branches with ganglion cells at nodal points. In all of our series certain of the most dorsally placed filaments of the plexus on the mesial surface of the olfactory bulb leave the fibers accompanying the vomeronasal branches as they pass through the cribriform area and course orally toward the upper and anterior part of the nasal septum, to participate in the formation of a plexus found in the deeper portion of the septal mucosa of this region. In the deeper portion of the septal mucosa anterior or oral to the region crossed by the vomeronasal nerves there is found a distinct plexus of terminalis fibers, associated with numerous small groups of ganglion cells, a plexus which reminds one of the enteric plexus, although the groups of ganglion cells are much smaller and the uniting nerve filaments much finer. That this anterior septal plexus is a part of the nervus terminalis distribution is shown on the one hand by the differential staining as found in our series, on the other hand by the fact that the more dorsally placed filaments of the nervus terminalis may be traced into this plexus as well as branches from the terminalis filaments which accompany the vomeronasal nerves. Numerous small groups of ganglion cells are found at the nodal points of this plexus, the number of ganglion cells constituting such a group varying greatly, varying from one cell to perhaps 10 or 15 cells. We have not observed branches of the nervus terminalis nor ganglion cells in the septal mucosa caudal to the region crossed by the vomeronasal nerves. The general peripheral distribution of the nervus terminalis of the rabbit, as also the disposition of the associated ganglia, is so clearly shown in figure 1, that further and fuller description seems to us unnecessary.

In our series it is possible to trace the branches of the trigeminal distribution to the nasal septum. In the main the nerve fibers of trigeminal origin appear to us as somewhat coarser, as stained more intensely black, and as presenting other characteristics, less distinct and more difficult to formulate, but evident to one who has studied the series carefully. The trigeminal branches to the nasal septum were confirmed as such in graphic reconstructions of the two younger stages, and in an incomplete reconstruction of the six day stage. It was found inadvisable to attempt to reproduce trigeminal distribution to the nasal septum in figure 1, since added to the structures already shown, the figure presented too complex a network of fibers to admit of following even the main nerve bundles in the reduced reproduction with any degree of certainty.

Two rather large branches of the trigeminal nerve enter this region; *a*, the rami mediales of the n. nasociliaris and *b*, the n. nasopalatinus. The former is from the first division of the trigeminal nerve and was traced from the Gasserian ganglion into the orbit, where it passes over the optic nerve and forward to enter the cranial cavity through the anterior ethmoidal foramen. Here it passes laterally about the base of the olfactory bulb and enters the nasal cavity through the anterior part of the cribriform plate. The larger rami mediales course along the anterior nasal wall to reach the septum about one third of the way down. Branches from these are distributed over the rostral and anterior part of the septum. The n. nasopalatinus was traced from the sphenopalatine ganglion, and at least a part of its fibers appear to have origin in the Gasserian ganglion, passing through the sphenopalatine ganglion. This nerve courses along the posterior part of the nasal septum as it leaves the sphenopalatine ganlion, toward the caudal end of the vomeronasal organ where it divides in two branches; one going to the palate, the other passing along the ventro-lateral border of the vomeronasal organ, giving off numerous branches which course upward and forward to reach the ventral and posterior or caudal portion of the nasal septum. Branches of this nerve are also distributed to the nasal septum caudal to the path of the vomeronasal nerve. Some of the smaller branches of the trigeminal nerve, especially those coming from the nasopalatine branch appear to join the plexus formed on the nasal septum by the nervus terminalis, others remain separate to their terminal twigs. This anastomosis of nerve filaments of Terminalis and Trigeminal origin renders it more difficult to determine the ultimate distribution of each. However, in no case was a ganglion cell or groups of such found on a nerve trunk clearly composed entirely of trigeminal fibers. A part of the nerve fibers leading from a group of ganglion cells could always be traced to nervus terminalis branches and in most cases all of the nerve fibers associated with a group of ganglion cells could be traced to nervus terminalis origin.

It seemed to us desirable to determine even approximately the number and distribution of the ganglion cells associated with the nervus terminalis. The results obtained are collated in the accompanying table. For the two older stages the number of ganglion cells as given appears to us to present the facts fairly accurately, in that it was possible to differentiate between ganglion cells and sheath cells with relative certainty. In the counts attention was paid largely to the nuclei, and only cells in which the nuclei were evident in a given section were counted for that section. For the two younger stages the count is, we believe, relatively high, since in the compact masses, especially in ganglia

TABLE 1

RABBIT	SERIES	SIDE	INTRACRANIAL PORTION	ALONG COURSE OF THE VOMERONASAL NERVE[1]	ON THE DISTRIBUTION OF THE NERVES ABOUT THE VOMERONASAL ORGAN[2]	NASAL SEPTUM ANTERIOR TO THE PATH OF VOMERONASAL NERVES	TOTALS
3 cm. embryo	A	R	163	181	409	120	873
	B	R	283	266	379	151	1079
Embryo about one week before birth	H	R	148	137	500	202	987
	Ha	R	158	127	455	174	914
1 day after birth	A	L	130	220	153	173	676
	B	R	120	205	132	166	624
6 days after birth	A	L	166	144	86	161	557
	A	R	93	139	117	119	468

[1] The vomeronasal cartilage was taken as the line of division between course and distribution of the vomeronasal nerve.

[2] The first four numbers of this column no doubt include sheath cells in the count.

found in the region of the vomeronasal organ, in which the cytomorphosis seems less complete, it was difficult to determine clearly between the nuclei of ganglion cells and the sheath cells.

A certain degree of uniformity will be noted in the figures presented for the two older stages. The figures given for the two younger stages for corresponding regions are throughout somewhat higher than for the two older stages. Especially is this noticeable in the column headed, "On the distribution of the nerves about the vomeronasal organ." In the two younger stages, as was noted, it was difficult in this region to differentiate clearly between sheath cells and ganglion cells, while in the other regions this differentiation was more readily made.

In the material at our disposal it is not possible to determine definitely and finally the character of the neurones composing the numerous small ganglia associated with the nervus terminalis. The evidence at hand is negative rather than positive. Throughout the several series the peripheral nerves are well stained. The cell bodies of the neurones are stained various shades of brown, the nuclei appearing as lighter or again as darker areas in the cytoplasm, often distinctly circumscribed. Many of the nerve cells present distinct evidence of a neurofibrillar network in the cytoplasm. The cell outline, however, is not always as distinctly and definitely brought to view as could be desired. The neurones of the sensory ganglia of the cranial nerves are throughout our series differentiated with distinct outline and sharply demarked processes. A want of distinct differentiation is on the whole also noted for the cranial autonomic ganglia. In the sphenopalatine ganglion of our series, the neurones are not distinctly outlined and their processes are not clearly brought to view. In figure 2, we have presented, for comparison, a group of detail figures comprising clusters of ganglion cells associated with a septal branch of the nervus terminalis, situated anterior to the path of the vomeronasal nerves, and small but characteristic areas taken from the Gasserian ganglia of the corresponding series. The nervus terminalis ganglia, one for each stage of our series, are arranged in vertical column to the left of the figure, placed chronologically, *A* to *D*, and designated by lower case '*a*'. The areas taken from the Gasserian ganglion of each of the respective stages of our series are chronologically arranged in vertical column to the right of the figure, and designated by a lower case '*b*.' A glance at the figure will show the distinct difference in the form and grouping of the nerve cells shown in the figures comprising the two columns. In column *a*, there are no distinct processes to the

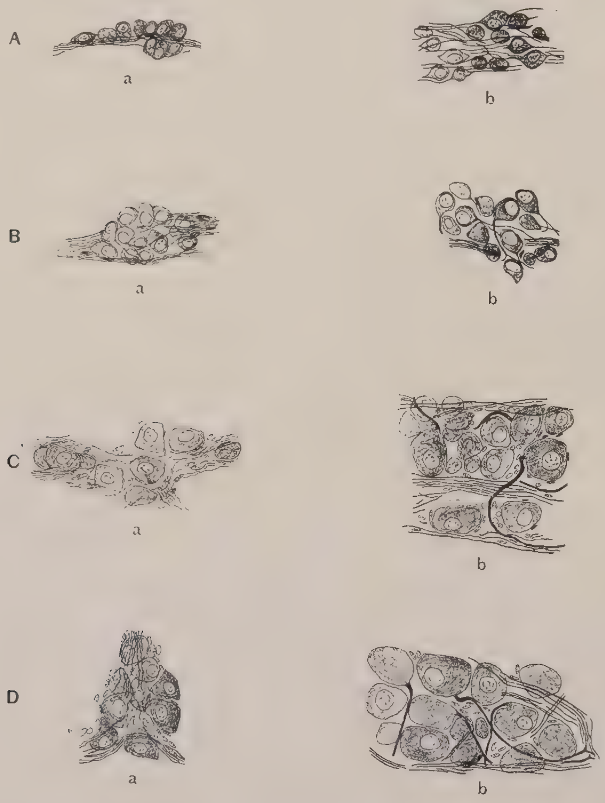

Fig. 2 Groups of ganglion cells of nervus terminalis and portions of the Gasserian ganglion from each of the stages of rabbit embryos and young rabbits used in this study. *A*, rabbit embryo, 3 cm. crown-breech length; *B*, rabbit embryo about one week before birth; *C*, young rabbit one day old; *D*, young rabbit six days old; *a*, ganglion cell groups taken from septal distribution of nervus terminalis, anterior to the path of the vomeronasal nerves; *b*, portions of the Gasserian ganglion. Pyridine-silver stain. × 200.

nerve cells and these are grouped around relatively fine nerve fibers. In column *b*, a progressive metamorphosis, characteristic for developing peripheral sensory or afferent neurones is noted. In *A*, *b*, from the Gasserian ganglion of a 3 cm. rabbit embryo the nerve cells are distinctly bipolar; in *B*, *b*, certain of the cells are unipolar with a short single process, presenting Y-shaped or T-shaped divisions; in *C* and *D*, *b*, neurones with long single processes dividing into central and peripheral branches as characteristic of afferent or sensory neurones, are evident. The series of figures *A* to *D*, *a*, present a structure which is very similar to that shown by the sphenopalatine and ciliary ganglia of the corresponding stages, as shown in our series. Even in the two older stages of our series, fixed by means of preliminary ammoniated acohol injection, the processes of the neurones of the autonomic cranial ganglia are not clearly brought to view. The statements here made relative to the ganglion cell groups found in connection with the septal portion of the nervus terminalis are equally pertinent when applied to the ganglion cell groups of its intracranial portion. In not one instance were we able to observe nerve cells, found in relation with the intracranial portion of the nervus terminalis of the rabbit, even in the 'ganglion terminale,' which presented clearly the characteristics of peripheral sensory or afferent neurones; and this in material in which the neurones of the sensory cranial ganglia were well characterized.

In figure 3, we present the very few instances in which neurones found in connection with the terminalis were distinctly stained, not the jet black of the ordinary chrom-silver preparations, as the figure would lead one to assume, but of a dark brown color with processes clearly brought to view. Cells *a*, *b*, and *c* of figure 3, are from the intracranial portion of the terminalis of a one-day-old rabbit. Cell *d*, of this figure is taken from a small group of ganglion cells found in connection with the septal portion of the terminalis of a rabbit, six days old. The nerve cells here shown present the morphologic characteristics of sympathetic neurones and are regarded as such. In *e*, of figure 3, is shown the one instance observed of a structure resembling a pericellular ending of a white ramus or preganglionic fiber in a sympathetic ganglion. This was observed at one edge of a small group of ganglion cells in the immediate vicinity of the 'ganglion terminale' of a one-day-old rabbit. It is sketched at a much higher magnification than are the nerve cells of the same figure. The coil complex appears too small to enclose the cell body of a sympathetic neurone, judging from adjacent nerve cells. We may dismiss this structure with the statement that its appearance suggests a pericellular ending of a white ramus or preganglionic fiber characteristic for sympathetic ganglia.

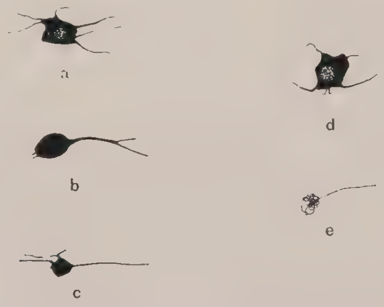

Fig. 3 Types of ganglion cells found in the course of the nervus terminalis, pyridine-silver staining; *a*, *b*, *c*, cells taken from the intracranial portion of a rabbit one day old; *d*, from septal portion of a rabbit six days old. × 200. *e*, a structure resembling a pericellular basket, the ending of a preganglionic nerve fiber, from the ganglion cell group of the intracranial portion of the nervus terminalis of a rabbit one day old. × 300.

As concerns the ultimate terminations of the nervus terminalis, our material is not wholly adequate to enable us to draw definite conclusions. We have been able to trace terminalis branches to certain blood vessels of the septal mucosa, but their ultimate endings have not been clearly determined. We are, therefore, not in a position to state whether such endings are to be regarded as of the type of free sensory endings distributed to the adventitial coat or motor endings distributed to the muscular coat. Terminalis branches in the older stages, especially in the six-day stage, have been traced to the ducts of septal glands, less clearly to the gland alveoli. Here also the ultimate endings have not been clearly defined. Ultimate terminalis branches have not been traced with certainty to the epithelium of the olfactory mucosa, although fine terminal nerve branches which are independent of the special sense cells, such as are described by authors, have been observed in the olfactory epithelium, especially that of the vomeronasal organ. As previously noted, terminal nerve filaments which were traced to trigeminal branches commingle here and there with the end filaments of the terminalis and this renders it difficult to speak with certainty concerning the ultimate distribution of the nervus terminalis.

A brief review of the literature dealing with the nervus terminalis of mammalia, and considered in the light of our investigations, may here be permitted. We have previously noted the work of Johnston and McCotter. To the references made the following may be added: Johnston's observations were made largely on sections of mammalian embryos, not stained with differential nerve stains. The Golgi method was used on pig embryos and an impregnation of the peripheral fibers obtained and the distribution of the terminalis to the vomeronasal organ verified. Whether a differential staining of the terminalis fibers was obtained is not stated. A few bipolar cells connected with its fibers were stained by the Golgi method. Extracranial ganglion cells were apparently not observed In the human embryos studied, a distinct ganglion terminale was noted and it is stated, "that the nervus terminalis joins with numerous strands of the olfactory nerve to make up the network of nerve bundles in the septum nasale." In the rabbit, as noted, the main septal branches of the terminalis are situated in a deeper plane in the mucosa than are the olfactory strands, and except for branches following the vomeronasal nerves, cannot be regarded as accompanying the olfactory nerves. We have not observed bipolar ganglion cells in the ganglion terminale nor in the more peripherally placed ganglia, and in our preparations these ganglion cells do not resemble peripheral sensory cerebro-spinal cells. McCotter has observed the intracranial portion of the nervus terminalis in adult dogs and cats with a ganglion terminale, and has traced it to its connection with the forebrain and the vomeronasal nerve. The methods used do not seem to admit of differentiation of terminalis and vomeronasal fiber, after these have joined. The fact that ganglion cells were found attached to the vomeronasal nerve just dorsal to the vomeronasal organ leads him to conclude that filaments of the terminalis "extend into the nasal cavity along with several filaments of the vomeronasal nerves and apparently terminate within or very close to the vomeronasal organ." This our preparations demonstrate conclusively for the rabbit.

Two other observers have dealt with the nervus terminalis of mammalia, namely DeVries and Döllken. The observations of DeVries extend to human and Guinea pig embryos. His results require but brief consideration, since, as agreed by authors who have reviewed his work, DeVries regards the nervus terminalis and the vomeronasal nerve as equivalent to the nervus terminalis of fishes, and believes that a similar structure is to be found in the whole vertebrate series. He recognized the vomeronasal nerve and the ganglion terminale or the vomeronasal ganglion, with a root entering the rhinencephalon on the mesial side of the olfactory lobe caudal to the olfactory bulb. Döllken had at his disposal an abundant material, consisting of mouse, rabbit, Guinea pig, pig an human embryos. His investigation is concerned largely with the central connections of the nervus terminalis. So far as concerns his observations on the peripheral distribution of this nerve we are convinced that he is dealing not only with the nervus terminalis but has included also the vomeronasal nerve. This Johnston has recognized. Döllken uses as synonyms the words 'ganglion terminale,' 'ganglion nasale,' 'ganglion vomeronasale' and 'Nebenbulbus,' and his statements concerning the peripheral branches of the terminalis, in all of the forms studied, lead us to believe that he has not differentiated between vomeronasal nerve and terminalis, regarding the latter as a special nerve to the vomeronasal organ. His text figures, 4, 5, and 6, given to illustrate the peripheral distribution of the terminalis and its relation to the vomeronasal organ and the ganglion terminale, as observed in rabbit embryos, which we are able to compare directly to our own, made this very clear to us. A comparison of text figure 6, rabbit embryo of 28 mm. with our youngest stage, rabbit embryo 3 cm. in which the nervus terminalis is differentially stained and can thus be clearly separated from the vomeronasal nerves, makes this confusion very evident. This observer describes for mouse embryos, numerous cells which he regards as nerve cells, in connection with the peripheral distribution of the terminals. I older stages in the course of the nerve only relatively few ganglion cells were observed. He states that the appearances presented seem to indicate that these cells are only necessary to further the growth of the nerve. One may presume, he adds, that the ganglion cells are nutritive organs, subserving the growth of the fibers to the sense cells and the centrally placed nerve cells, the nerve cells after completion of their function undergoing regression, their fibrillae forming other relations in the course of the nerves. In the rabbit also, the ganglion cells found in the course of the nervus terminalis are said to show regression as development proceeds. Our observations on the rabbit, and especially such as pertain to older stages than those studied by Döllken, warrant the statement, that there is no material reduction in the number of ganglion cells found in connection with the terminalis as development proceeds. In a human embryo of 21 mm. crown-breech length and in an older stage, presumably 35 mm. crown-breech length, Döllken observed numerous cells in the ganglion terminale which, after silver impregnation, showed great resemblance to the cells of the intervertebral and head ganglia, and which were apparently further developed than were the cells of the Gasserian ganglion. As stated by Johnston, Döllken "has failed to recognize the clear distinction which exists between ganglion terminale and the cells lying along the olfactory nerve fibers ('olfactory ganglion') which later produce neurilemma cells," and with this we agree. In all of our preparations of rabbit material there is evident a distinct difference in the form and the relations of the ganglion cells of the nervus terminalis and of those of the Gasserian ganglion. Since Döllken has not differentiated between the fibers of the nervus terminalis and vomeronasal nerve fibers his statements concerning the ultimate distribution of the terminalis fibers must be interpreted with this fact in view. We have not in our preparations, with differentially stained terminalis fibers, been able to trace with certainty ending of these fibers into the epithelium of the vomeronasal organ, and are thus disposed to regard the fine nerve fibers found in the olfactory epithelium and not connected with the special sense cells as very probably, in part at least, of trigeminal origin. As concerns Döllken's observations on the central origin of the nervus terminalis we may state that we have not observed the four roots of entrance as described by him. His root 'c' corresponds closely with the main terminalis root as observed by us, in this we agree with Johnston. The small root entering more dorsally, as noted by us, may correspond with Döllken's root 'a'. The other roots we have not observed.

The literature dealing with the nervus terminalis of vertebrates other than mammalia requires but brief consideration, since it has been dealt with in several of the recent contributions and since in the majority of the studies stress is laid on the central connections rather than on the peripheral distribution, which was not always clearly followed. For reptilian embryos Johnston has described groups of ganglon cells found at intervals along the dorsal division of the olfactory nerve, which he attributes to nervus terminalis. An instance in which ganglion cells are found on the peripheral portion of this nerve. It is a question in our minds as to whether the olfactory ganglion, a part of the trigeminal complex as described by Rubaschkin for chick embryos, is to be considered as related to the terminalis. This olfactory ganglion is described as lying under the dorsal and caudal portion of the olfactory mucous membrane and contains in the main bipolar cells, with peripheral processes traced into fine filaments which end in the olfactory epithelium and central processes traced to the Gasserian ganglion. Further observations made in the light of more recent investigations, seem necessary before the relations of the 'olfactory ganglion' to the ganglion terminale can be determined.

Of the more recent contributions dealing with the nervus terminalis in amphibia and fishes, the following may be mentioned briefly. Herrick, in the frog, was unable to trace terminalis fibers further than "1 mm. beyond olfactory bulbs." Accordingly he does not assign a distribution although he assumes that it accompanies olfactory strands, since ganglion cells are found scattered along the course of some of the latter. McKibben, in urodele amphibia, was able to follow the nervus terminalis only some 2 mm. distal to its superficial origin, and thus does not give its distribution. Sheldon, in the carp, states that terminalis fibers "are distributed to the epithelium with olfactory fibers." Brookover, for Amia and Brookover and Jackson, for Amieurus, give the peripheral distribution as associated with the olfactory strands. Sewertzoff reports that in Ceratodus forsteri, the distribution is to the anterior part of the nasal cavity and to the ordinary, not olfactory epithelium, and is decidedly of the opinion that it "does not serve an olfactory function." In this he is quite at variance with the conclusions of Brookover who regards the nervus terminalis as a component of the olfactory nerves. Brookover and Jackson reach the same conclusion regarding the nerve in Amieurus, basing their opinion on embryologic evidence. The majority of authors dealing with the nervus terminalis appear to have regarded it as an afferent nerve, homologous with the cutaneous sensory nerves of other regions. Brookover suggests that it may be of vasomotor function, and Brookover and Jackson express the same opinion, although in both articles it is admitted that there is no definite evidence. The evidence given by Brookover for connecting the nervus terminalis to the post optic sympathetic system by way of the intracranial sympathetic system, which he described, seems insufficient to us to establish this connection. We quote his summary of the evidence: "The nature of the Golgi impregnation on which I have had to depend to a large extent for tracing these intracranial fibers does not permit of demonstrating the connections between the nervus terminalis and the posterior portion of the sympathetic as clearly as would be the case with medullated fibers by the Weigert method, but the slightly diminished bundle of fibers of fig. 22 (intracranial sympathetic, our insertion) certainly continues rostral along the carotid artery beneath the olfactory nerve, while the fibers of the nervus terminalis just as certainly become more or less distinctly separated from the olfactory nerve, after it enters the cranial cavity, and run near the same artery." In certain of our series we find small bundles of nerve fibers, such as he describes accompanying the various intracranial blood vessels situated under the anterior part of the brain and olfactory bulbs, and passing in very close proximity to nervus terminalis strands without observing any anastomosis of nerve fiber bundles of the respective systems. We consider, therefore, that in order to establish a connection in this region it is necessary to show an actual fiber continuity, not a mere proximity.

After thus considering briefly the literature, we may proceed to our own conclusions.

CONCLUSIONS

Our observations on the nervus terminalis of the rabbit warrant, we believe, the following statements:

By reason of the differential staining of the nervus terminalis, in all of the stages of our series, we conclude that this nerve is not a component part of the olfactory and vomeronasal complex, but an independent nerve, with central connections by means of several small roots to the ventro-mesial and mesial portion of the forebrain, caudal and independent of the olfactory stalk, and courses in the form of a loose plexus along the ventro-mesial surface of the olfactory bulb, reaching the nasal septum on the mesial surface of the vomeronasal nerve, which nerve it follows to the mucosa of the vomeronasal organ, and is further distributed to the septal mucosa anterior to the path of the vomeronasal nerve, in which region especially it is joined by terminal branches of the trigeminus, mainly from the nasopalatine branches.

In the course of this nerve, even in connection with its more peripheral branches and beginning with its intracranial portion, there are found numerous smaller and larger groups of ganglion cells. One of these groups, of relatively larger size than the other, is situated on its intracranial portion in the region where the terminalis approaches the vomeronasal nerve. This larger group is regarded by us as the ganglion terminale of authors.

The groups of ganglion cells found in the course of the nervus terminalis of the rabbit present the appearance of small sympathetic ganglia, similar in general structure and appearances to cranial autonomic or sympathetic ganglia found in our series, and differing in form and arrangement of neurones from those of the intervertebral and cranial afferent sensory ganglia of the respective series. The nerve fibers of the terminalis have more the appearance of sympathetic and preganglionic fibers than of neuraxes or dendrites of sensory neurones.

Distribution of ultimate terminalis branches to blood vessels and glands of the septal mucosa seems probable, though this we cannot assert positively since the commingling of trigeminus and terminalis terminal filaments has been observed.

For the present we reserve definite statement as to the probable function of the nervus terminalis of the rabbit, realizing fully that further work with the introduction of other methods is necessary. If we consider only the peripheral distribution of the nerve, the size of its component fibers, its arrangement in loose plexus, character, number and disposition of associated ganglion cell groups, we should favor ascribing to it an autonomic function. Its central connection, however, both in character and place of origin, does not wholly conform with our conception of deep and superficial origin of the preganglionic nerve fibers of a sympathetic path.

BIBLIOGRAPHY

The literature here listed does not include nearly all of the contributions dealing with the nervus terminalis and olfactory and vomeronasal nerves which have been consulted. The literature dealing with the nervus terminalis in mammalia is included, and of the other papers only the more recent and pertinent ones.

Brookover, Charles 1910 The olfactory nerves, the nervus terminalis and the preoptic sympathetic system in Amia calva. Jour. Comp. Neur., vol. 20.

Brookover, Charles, and Jackson, T. S. 1911 Olfactory nerve and nervus terminalis of Amieurus. Jour. Comp. Neur., vol. 21.

DeVries, E. 1905 Note on the ganglion vomeronasale. K. Akad. van Wetenschappen te Amsterdam, vol. 7.

Döllken, A. 1909 Ursprung und Zentren des Nervus Terminalis. Monatsch. f. Psych. u. Neur. Bd. 26, Ergenz. Heft.

Herrick, C. Judson 1909 The nervus terminalis in the frog. Jour. Comp. Neur., vol. 19.

Johnston, J. B. 1913 The nervus terminalis in reptiles and mammals. Jour. Comp. Neur., vol. 23.

McCotter, R. E. 1913 The nervus terminalis in adult dog and cat. Jour. Comp. Neur., vol. 23.

McKibben, Paul S. 1911 The nervus terminalis in urodele amphibia. Jour. Comp. Neur. vol. 21.

Rubaschkin, W. 1903 Über die Beziehungen des Nervus Trigeminus zur Riechschleimhaut. Anat. Anz., Bd. 22.

Sewertzoff, A. N. 1902 Zur Entwickelungsgeschichte des Ceratodus forsteri. Anat. Anz., Bd. 21.

Sheldon, R. E. 1909 The nervus terminalis in the carp. Jour. Comp. Neur., vol. 19.

THE ATRIO-VENTRICULAR CONNECTION IN THE REPTILES

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SEVEN FIGURES

In connection with some physiological experiments on the coordination of the reptile heart and its disturbance (Laurens '13), I have undertaken an histological examination of the hearts of these animals with particular reference to the atrio-ventricular connection and should like to report briefly the results of this investigation. Such an histological study seemed necessary not only as supplementary to the physiological experiments but also owing to the contradictory views which are expressed about this region of the reptile heart.

On looking over the literature dealing with the anatomy of the tortoise and lizard hearts one is struck by the lack of accurate and clear accounts of the connection of one part of the heart with another, as well as of the distribution of the nervous elements in the heart. This is true for the tortoise, but much more so for the lizard. In the case of the latter one finds the contradictory views of Imchanitzky, that there is no muscular connection between the atria and the ventricle, and of Külbs and Lange, that the heart of the lizard consists of four parts which are connected muscularly. Again, while Imchanitzky describes a nerve plexus with very large and small ganglion cells, by means of which the auricles are connected with the ventricle, Külbs and Lange have never found nerves and ganglion cells in their muscular atrio-ventricular connection.

In the paper referred to the literature dealing with the anatomy of the atrio-ventricular connection in the reptiles was reviewed in full, so that there is no need to do so again.[1] The conclusion which is to be derived from a reading of this literature was there stated, (p. 148) and is, that between the auricles and ventricle of the reptile heart a muscular connection undoubtedly does exist. The results of Dogiel ('07) and Imchanitzky ('09) however, stand in direct opposition to this view. According to them, the different parts of the heart are not connected muscularly, and the connection between the auricles and ventricle is effected solely by means of a large nerve bundle which runs in a band of connective tissue on the dorsal side of the heart. Dogiel called this band of tissue the 'Ligamentum Atrioventriculare.'

The same species of lizards (L. viridis and agilis) and of tortoise, (Clemmys lutaria) as were used for the physiological experiments have been examined histologically. In addition, the hearts of the sculptured tortoise (Chelopus insculptus) and of the common box tortoise, (Cistudo carolina) and one heart of a snake, (Storeria dekayi) have also been studied. The hearts were fixed in Flemming's strong solution or in concentrated corrosive sublimate, imbedded in paraffin and sectioned, 5 to 7 μ in the case of the lizards and 10 to 15 μ in the case of the tortoises. For staining, Heidenhain's iron hematoxylin, followed, after differentiation, by van Gieson's picrosäurefuchsin mixture was used and gave excellent results. By this method a beautiful differentiation between muscular and connective tissue is obtained and the striated musculature is finely shown. Good accounts of the general anatomy and histology of the different parts of the lizard and tortoise hearts will be found in the literature referred to. I wish to give only a brief description of the connection between the auricles and the ventricle—the atrio-ventricular funnel—and of the intra-cardial nervous system as far as I have been able to carry out this part of the work.

The atrio-ventricular connection in the lizard and tortoise hearts may be described together, since in the species examined by me the conditions, as far as I have been able to make out, are identical. The drawings, which were made with the aid of the camera lucida, are all of the lizard heart, (L. agilis.)

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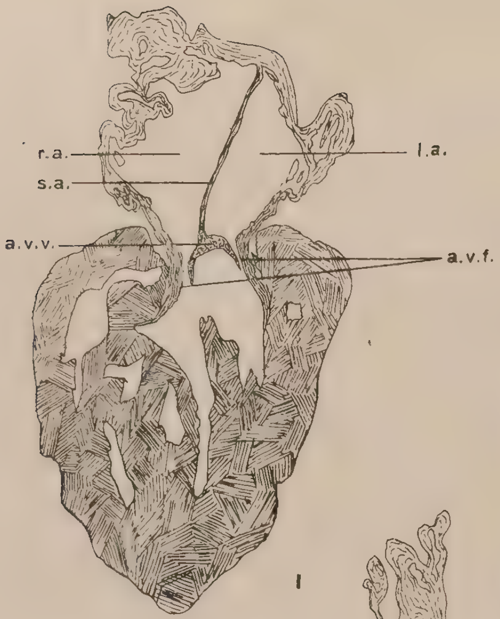
[1] The work by Greil, which was unknown to me at the time, should be here mentioned. Greil speaks of and figures, though he does not describe in any detail, an 'Aurikular' or 'Atrio-ventrikularring' of musculature, by means of which the auricles and ventricles of various reptiles including the lizard and tortoise, were connected.

In frontal and sagittal sections, (figs. 1, 2 and 3), the auricles, separated by the septum, can be seen to extend downward in the form of a closed tube, which is more or less funnel shaped, into the cavity of the ventricle. A cross-section (fig. 4) through the base of the ventricle, a little below the level at which the septum goes over into the atrio-ventricular valves, shows the atrio-ventricular funnel to be a closed ring, clearly separated from the ventricle by a fairly thick layer of connective tissue, in which numerous blood vessels and ganglion cells are to be seen. As the funnel extends farther into the ventricular cavity it approaches nearer and nearer to the ventricle, at the same time becoming thinner, particularly on the dorsal side. The connective tissue between the funnel and the ventricle also becomes less in amount and finally the two kinds of musculature are in direct contact. In a cross section (fig. 5.) through the ventricle, nearer the apex, and at a level a little below that represented by the line *a.v.v.* in figure 2, it is seen that the funnel of musculature is no longer in the form of a closed ring, but that it is now interrupted on the ventral side by the vessels of the bulbus with the walls of which it becomes connected. At about the same level on the dorsal side the funnel musculature has become directly connected with that of the ventricle. Thinning out gradually, it can be seen to go over into that of the ventricle. From this first dorsal place of connection the junction of the two forms of musculature spreads to the right and to the left, and the last parts of the funnel to become connected with the ventricle are the two sides, right and left (fig. 6) and of these the left extends further into the ventricle, than does the right. A part of the original funnel on the left ventral side (fig. 6) persists for a considerable time after all the remainder has disappeared, and finally becomes connected with the inner wall of the ventricle.

The musculature of the funnel goes over directly into that of the ventricle. The fibers of the funnel are arranged circularly, and there is a good deal of connective tissue in among them as



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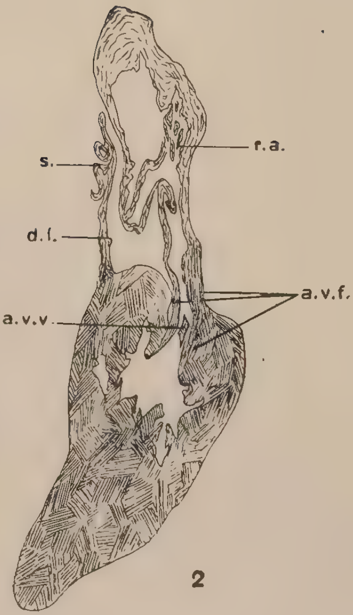

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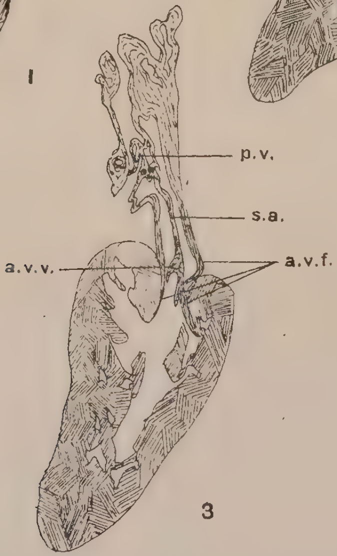

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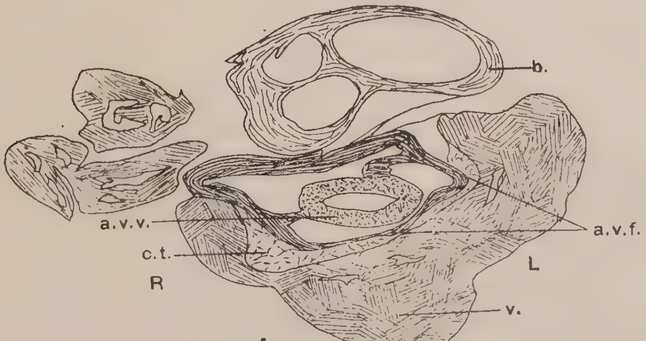
Figs. 1 to 7 All the figures are of the lizard heart (Lacerta agilis) and were drawn with the aid of the camera lucida.

Fig 1 Frontal section through the whole heart at a level slightly ventral to the horizontal median line; *a.v.f.*, atrio-ventricular funnel; *a.v.v.*, atrio-ventricular valve; *l.a.*, left auricle; *r.a.*, right auricle; *s.a.*, septum atriorum. × 20.

Fig. 2 Sagittal section through the right side of the heart; *a.v.f.*, atrio-ventricular funnel; *a.v.v.*, atrio-ventricular valve; *d.l.*, dorsal ligament; *r.a.*, right auricle; *s.*, part of the sinus venosus. × 20.

Fig. 3 Sagittal section through the left side of the heart just median to the entrance of the pulmonary vein; *a.v.f.*, atrio-ventricular funnel; *a.v.v.*, atrio-ventricular valve; *p.v.*, pulmonary vein; *s.a.*, septum atriorum. × 20.

well as numerous capillaries. The funnel musculature can easily be distinguished from that of the ventricle on account of its brighter appearance, as it does not stain so deeply. Differences in the striation of the muscle fibers and in the size and shape of the nuclei are also apparent. The fibers and nuclei of the muscle cells of the funnel are similar to those of the auricles. The striation is very distinct but fine, and the nuclei are large and round or slightly oval. The ventricular fibers are more coarsely stri-



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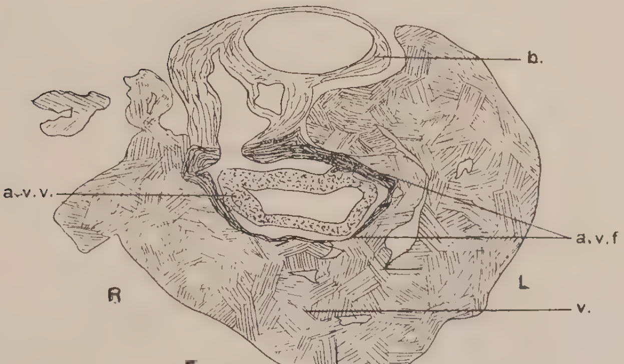

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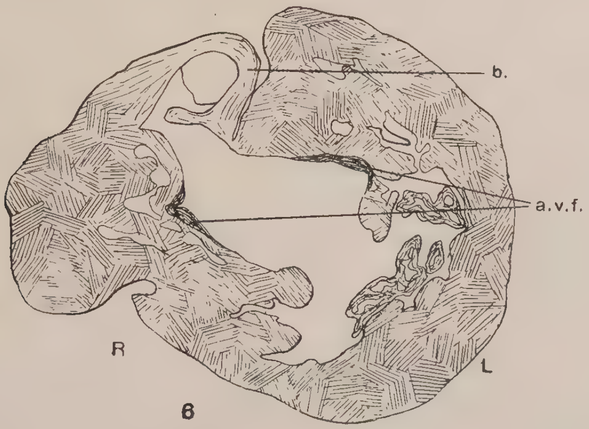
Fig. 4 Cross section through the ventricle just below the atrio-ventricular groove; *a.v.f.*, atrio-ventricular funnel; *a.v.v.*, atrio-ventricular valve; *b.*, bulbus; *c.t.*, connective tissue. × 40.

Fig. 5 Cross section through the ventricle nearer the apex than in figure 4 and at about the level represented by the line *a.v.v.* in figure 2; *a.v.f.*, atrio-ventricular funnel; *a.v.v.*, atrio-ventricular valve; *b*, vulvus; *v.*, ventricle. × 40.

ated, and the nuclei are long and narrow. Further, the muscle fibers of the funnel and of the ventricle run in different directions, so that there is little difficulty in distinguishing the two.

The smooth muscle cells described by Bottazzi ('07) as occurring in the auricles of the tortoise, Emys europaea, are seen very clearly in the auricles of all the tortoises that I have examined. They occur, as Bottazzi described them (p. 171), as a layer immediately under the endothelium of the auricles and are a continuation of the tunica media of the large veins. I have not been able to follow them into the ventricle. Oinuma ('10) has recently referred the oscillations in tone of the auricles of the tortoise, as well as the lasting increase in tonus, to the activities of this smooth musculature. In earlier investigations Bottazzi ('97) could not find any trace of these variations in tone in the auricles of several batrachian and reptilian hearts, one of which was the lizard, Lacerta viridis. I also could never see these variations in tone in the auricles of the lizard and have looked in vain for the presence of smooth muscle cells in the auricles of both L. viridis and agilis.

The connection which Dogiel and Imchanitzky describe as existing between the auricles and ventricle of the tortoise and lizard has been shown to have absolutely no significance for the co-ordination of the heart (Laurens '13, pp. 144 and 159). Since it is claimed by these authors to be the sole means of connection between the auricles and the ventricle, I have studied it carefully both in the pulsating heart and in sections. On the dorsal side of all the lizard and tortoise hearts that I have examined there is to be seen a direct connection, which I have called the dorsal ligament, between the sinus and the ventricle. It is well over to the right side (figs. 2 and 7) and appears as a broad, flat band in which, under the binocular, nerves and blood vessels can be seen. The coronary vein and the 'coronary nerve' or nerves (Gaskell) do not run free, but in this band of tissue, which is a fold of the pericardium. In sections, the band, or dorsal ligament, is seen to be made up of connective tissue which begins at the sinus venosus and runs superficially over the auricles and the auriculo-ventricular groove to end on the dorsal surface of the ventricle. Along its course are found several collections of ganglion cells and blood vessels. It therefore does not connect the auricles with the ventricle, as Dogiel and Imchanitzky claim, but is a pathway between the sinus and the ventricle for nerves and blood vessels.



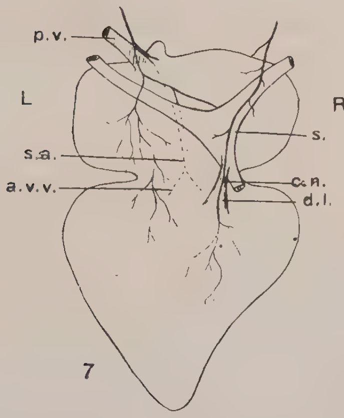


Fig. 6 Cross section through the ventricle below the level of the atrio-ventricular valves, *a.v.f.*, atrio-ventricular funnel; *b.*, bulbus. × 40.

Fig. 7 Dorsal view of the heart to show the nerves; *a.v.v.*, atrio-ventricular valve; *c.n.*, the 'coronary nerve;' *d.l.*, the dorsal ligament; *p.v.*, the pulmonary vein; *s.*, the sinus venosus; *s.a.*, the septem atriorum.

The innervation and intracardial nervous system of the reptile heart has been described by a number of investigators. I have succeeded in staining the intracardial nervous system of the isolated lizard heart by means of methylen blue. Owing to the difficulty of obtaining material at the time of year at which my observations were made they have not been carried very far. It is my intention to continue this work and to make a detailed study of the intracardial nervous system of the lizard. The preparations which I have made show the auriculo-ventricular funnel richly supplied with nerves, contrary to the opinion of Külbs and Lange, and have convinced me that a separation of the nerves and musculature of this connection are hardly any more possible in the lizard heart than in that of any other vertebrate. In my material fixed in Flemming's solution and corrosive sublimate the ganglion cells are very well preserved and the account of the intracardial nervous system is in part taken from sections of these hearts. The lizard heart (L. viridis and agilis) (see fig. 7) is supplied by two nerves, which, according to Külbs and Lange, are branches of the vagi, the left nerve supplying the most of the heart. The right divides just cephalad of the heart into two branches, the one passing to the dorsal, the other to the ventral side and supplying the bulbus. The dorsal branch runs to the sinus, fine branches ramifying over its walls and other small branches supplying the right auricle. A large branch runs directly from the sinus to the ventricle along the dorsal ligament. This branch can be called the 'coronary nerve' since it corresponds to the nerve of that name in the tortoise heart. All along its course are found ganglion cells, which decrease in number as the ventricle is approached. This nerve does not enter the auriculo-ventricular groove, as Gaskell describes for the tortoise, a condition which I have also not been able to verify in that animal, but spreads out over the dorsal surface of the ventricle. The left nerve has a larger surface to supply. It gives off first a large branch which enters to the median side of the single pulmonary nerve, where, in sections a very large ganglionic mass can be seen, which almost surrounds the opening of the vein into the left auricle. The main branch of the left nerve enters the heart at the opening of the sinus to the right auricle where again in sections a large collection of ganglion cells is seen. Previous to entering the heart it gives off a small branch which enters the right auricle near the beginning of the septum and runs along it with ganglia in its course. From the main branch there are also several other branches given off which ramify over the dorsal wall of the left auricle and, crossing the auriculo-ventricular groove, pass to the ventricle (fig. 7).

From the examination of the sections, several collections of nerve cells are to be seen. The largest and most conspicuous of these are two at, or around, the entrances of the veins into the auricles. In the dorsal ligament the nerve cells are very numerous and often aggregated into masses of eight to ten cells each. In the connective tissue of the auriculo-ventricular groove numerous scattered nerve cells are seen, sometimes very closely in connection with the funnel musculature. In the septum atriorum there are two ganglionic masses, the first near the beginning of the septum, the other very near the atrio-ventricular valves. In the auriculo-ventricular funnel ganglion cells seem to be scarce, and I have seen them scattered only here and there, and chiefly on the ventral side. I have not been able to see ganglion cells in the musculature of the ventricle and of the bulbus. Imchanitzky, using methylen blue, has been able to demonstrate nerve cells through the whole ventricle, they being most numerous in the neighborhood of the bulbus aortae.

In the tortoise nerves can be seen running along the superior venae cavae to the heart. On the right side it can be seen that a branch ('coronary nerve') runs directly from the sinus under the vein to the ventricle, the remainder of this nerve being distributed to the sinus, and perhaps a small branch to the right auricle. The nerve on the left side is distributed principally to the left auricle from which can be made out several branches which run to the ventricle along the auriculo-ventricular groove, some ending here and others continuing on to the dorsal surface of the ventricle. Running to the ventral side of the heart are several fine branches which divide and are distributed to the different vessels of the bulbus aortae.

Groups of ganglia are more numerous in the tortoise heart than in that of the lizard. The largest are again two at the opening of the sinus and of the pulmonary veins into the auricles. In the dorsal ligament there are numerous groups of ganglia all along the course of the 'coronary nerve.' On the dorsal side of the left auricle, just under the pericardium there are numerous small groups of ganglia to be seen, some consisting of only two or three cells. At the beginning of the septum atriorum, on the right side, there is a collection of ganglia and also several small groups of nerve cells along this side of the septum. In the connective tissue of the auriculo-ventricular groove, particularly on the left side, and in the connective tissue in the proximity of the bulbus, the ganglionic masses are very numerous, though small, consisting of from two to five cells. When traced through the sections the nerve cells in the connective tissue of the auriculo-ventricular groove are seen to be connected with those of the bulbus.

It was found from physiological experiments (Laurens '13, p. 176) that in the reptile heart there is a certain amount of differentiation in the atrio-ventricular conduction paths. The right and left sides of the atrio-ventricular funnel were found to have the power of retaining co-ordinated the sequence of ventricular upon auricular beat when other parts of the connection were cut away. The left ventral side seemed more important than the right in preserving this co-ordination.

These physiological results stand in accord with those obtained from histological examination. As has been pointed out the auricles and ventricle are connected by a muscular funnel which extends down from the auricles into the cavity of the ventricle and becomes connected with its musculature. There is no such 'ring' as Gaskell describes, and the two kinds of musculature go over directly into one another. The fibers of the funnel are arranged circularly, but this arrangement can in no way be regarded as a well defined ring in the sense in which Gaskell used it.

The differentiation in function of the atrio-ventricular connection can, I believe, be explained in the light of the structural conditions. Gaskell ('84, p. 67) described a certain part of the muscular connection which had more than any other part the property of preserving the co-ordination between the auricular and ventricular beat when the remaining portions were cut away. This part was on the right ventral side under the aorta. Külbs ('12) explains Gaskell's results on the assumption that there is found the direct connection between the auricular and the bulbus musculature. A slightly different explanation seems to me to fit the case better than the one suggested by Külbs. As Keith and Flack ('07) have emphasized, the muscular atrio-ventricular connection in the reptiles is, in cross section, a ring, extending completely around the atrio-ventricular ostium, but in which there is evidence of concentration in that the tissue is more abundant at certain points than at others. The more recent investigations of Keith and Mackenzie ('10) corroborate this opinion. In cross sections of the lizard heart it is seen that there is evidence of concentration in that the musculature of the atrio-ventricular connection is thickest on the ventral side and to the right and left, and thinned out on the median dorsal side. When sections nearer the apex of the ventricle are examined (figs. 5–6) it is seen that it is the right dorsal and left ventral sides which are thicker than any other part. As has been pointed out, these are the parts of the atrio-ventricular funnel which are most intimately connected with the ventricular musculature, and in this fact, in my opinion, is to be found the explanation of the greater power of this part of the connection to preserve the co-ordination of the heart-beat. The fibers of these bundles of musculature, and particularly the left one, extend further into the ventricular cavity than do any other parts of the original muscular funnel and joining gradually along their course with the ventricle they form a stronger connection between auricles and ventricle than elsewhere. From a glance at the sketches of lizards' hearts (Laurens '13) shown in figures 18, 27, and 38, and of the tortoise heart, figure 41, which were drawn under a binocular after the experiment for which they had been used, had been concluded, it will be seen that the bridge of tissue shown as the sole means of connection between auricle and ventricle corresponds very closely to that part of the funnel musculature represented to the right and left in figure 6.

SUMMARY

1. The auricles and ventricle of the lizard and tortoise are connected muscularly.

2. The atrio-ventricular connection is in the form of a tube, which extends downward from the auricles and is pushed funnel-shaped into the cavity of the ventricle, with the muscular walls of which it becomes directly connected.

3. The differentation in function of the atrio-ventricular funnel is in accord with the structural conditions, in that the right and left sides which show the greatest power of preserving the co-ordination extend more deeply into the ventricular cavity and are more intimately connected with its musculature than are any other parts of the funnel.

4. The dorsal ligament ('Ligamentum Atrioventriculare' of Dogiel), connects the sinus with the ventricle. Along it runs a branch of the right vagus, the 'coronary nerve' from the sinus to the ventricle.

5. The atrio-ventricular funnel is richly supplied with nerves. Ganglion cells are, however, scarce.

LITERATURE CITED

Bottazzi, F. 1897 The oscillations of the auricular tonus in the batrachian heart. Jour. Physiol., vol. 21, pp. 1–21.

1907 Richerche sulla musculatura cardiale dell' Emys europaea. Zeitschr. f. Allg. Physiol., Bd. 6, S. 140–194.

Dogiel, J. 1907 Einige Daten zur Anatomie des Frosch- und Schildkrötenherzens. Arch. f. mikroskop. Anat., Bd. 70, S. 1–96.

Gaskell, W. H. 1883 On the innervation of the heart with especial reference to the heart of the tortoise. Jour. Physiol., vol. 4, pp. 43–127.

GREIL, A. 1903 Beiträge zur vergleichenden Anatomie und Entwicklungsgeschichte des Herzens und des Truncus arteriosus der Wirbelthieren. Morph. Jahrb., Bd. 31, S. 123–310.

IMCHANITZKY, M. 1909 Die nervöse Koordination der Vorhöfe und Kammer des Eidechsenherzens. Arch. f. Anat. (und Physiol.), S. 117–136.

KEITH, A., AND FLACK, M. 1907 The form and nature of the muscular connections between the primary divisions of the vertebrate heart. Jour. Anat. and Physiol., vol. 41, pp. 172–189.

KEITH, A. AND MACKENZIE, IVY 1910 Recent researches on the anatomy of the heart. Lancet, vol. 1, pp. 101–103.

KÜLBS 1912 Über das Reizleitungssystem bei Amphibien, Reptilien, und Vögeln. Zeitschr. f. exper. Pathol. und Therapie, Bd. 11, S. 51–68.

KÜLBS UND LANGE, W. 1910 Anatomische und experimentelle Untersuchungen über das Reizleitungssystem in Eidechsenherzen. Zeitschr. f. exper. Pathol. und Therapie, Bd. 8, S. 313–322.

LAURENS, H. 1913 Die Atrioventrikuläre Erregungsleitung im Reptilienherzen und ihre Störungen. Pflüger's Archiv., Bd. 150, S. 139–207.

OINUMA, S. 1910 Beiträge zur Physiologie der Autonom innervierten Musculatur. III. Über den Einfluss des Vagus und des Sympathicus auf die Tonusschwankungen der Vorhöfe des Schildkrötenherzens. Pflüger's Archiv., Bd. 133, S. 500–518.

ANATOMICAL OBSERVATIONS ON A LIPOMA SIMULATING DIRECT INGUINAL HERNIA

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TWO FIGURES

During class work while a dissection was being made of the inguinal regions of an adult male cadaver, for the purpose of studying the anatomy of inguinal hernia, a lipomatous development was found to exist, that arose from the subperitoneal tissue beneath the triangle of Hesselbach on the left side of the body. The growth had followed the course usually taken by a direct inguinal hernia in the lateral and inferior third of the triangle.

Fatty herniae have been known since the earlier days of anatomical investigation, as will be seen by review of the literature. Those who have chiefly contributed to the subject are the following: Morgani (1), Pelletan (2), Scarpa (3), Sir Astley Cooper (4), Cloquet (5), Maunder (6), Paget (7) and Gascoyen (8), Annandale (9), Wernher (10), Gay (11), Butlin (12), Tillaux (13), Stonham (14), Hutchinson (15), Broca (16), Douglas (17), Imbert (18), and Shattock (19), in 1908–09, gave the results of his investigation "On normal tumor-like formations of fat in man and the lower animals."

The normal disposition of adipose tissue in the body is an important factor in the study of the subject. Its vagaries of distribution and sites of predilection are well known at the present day, but the causes for development in localized areas are not known. The dissecting room is a fruitful field for their discovery and study. Their distribution in the regions of inguinal herniae may be summed up as follows:

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1. Their development in the subperitoneal connective tissue about the abdominal inguinal ring and their subsequent descent through it, into and along the inguinal canal to emerge through the subcutaneous ring.

2. Their development within the spermatic cord itself at any point of its course within the canal after the convergence of its constituents at the abdominal ring, or after its emergence through the subcutaneous ring.

3. Their development within the inguinal canal about the cord, in the lateral, median or medial thirds of the canal, and their subsequent emergence at the subcutaneous ring.

4. Their development in the superficial fascia over the inguinal canal, subcutaneous ring, and cord before it reaches the scrotum.

5. Their development in the subperitoneal tissue beneath the triangle of Hesselbach and their subsequent emergence, by rupture or the yielding of structures in that area, so as to enter the inguinal canal and emerge through the subcutaneous ring.

6. Their development between the abdominal muscles about the inguinal canal and Hesselbach's triangle.

7. Their development in the prevesical space and appearance at the subcutaneous ring, as in a case reported by Imbert, where a lipoma presented by way of the middle inguinal fossa.

8. Origin from the subperitoneal fat in the iliac fossa has been observed several times by Prof. A. W. Meyer, though unreported.

It is not the purpose of the present paper to consider the subject from a pathological standpoint, but to present it from the viewpoint of anatomy. The incentive for reporting the present facts is the observation made in the dissecting room on the case above mentioned, where a lipoma simulated direct inguinal hernia. The anatomical relations presented by the growth and contiguous structures were very clear and definite in that case. The instance also presents an opportunity for making some critical remarks on the anatomical terminology involved in the anatomy of direct inguinal hernia.

ANATOMICAL CONSIDERATIONS

Hesselbach's triangle is a space between the inguinal ligament inferiorly, the inferior epigastric artery laterally and the lateral edge of the rectus muscle medially. The dorsal boundary of the triangle is formed directly by the fascia transversalis, more deeply by the subperitoneal tissue and peritoneum. The ventral covering for the medial two-thirds is the so-called conjoined tendon, for the lateral and inferior one-third the cremasteric muscle and fascia which take the place of the conjoined tendon; while more superficially are the aponeurosis of the external oblique, superficial fascia and integument.

The size of the triangle is subject to considerable variation, and as Cloquet states depends in extent upon the distance of the inferior epigastric artery from the symphysis pubis. It also varies with the development of the rectus muscle. Measurements of the boundaries of Hesselbach's triangle in four cadavers gave an average of 45 mm. for the base at the inguinal ligament; 55 mm. for the medial boundary and 65 mm. for the lateral boundary. The variation was not over 5 mm. and that was chiefly in the lateral and medial boundaries, depending upon the variation in the obliquity of the inferior epigastric artery.

The aponeurosis of the abdominal muscles vary in their degree of uniformity of thickness, and consequently in the power of resistance. At times there is more or less equality in the distribution and arrangement of the structures and therefore approximately of equal strength throughout; at other times certain areas are relatively weak and deficient at certain points. Usually when well developed the aponeuroses are opaque; when poorly developed more or less translucent. These variations depending upon developmental and other conditions. The extremes of the development may be observed, on the one hand, in the well developed abdominal muscle of the athlete or of the laborer; on the other, in individuals of under development or of sedentary habits, and as is well known the anterior abdominal walls are occasionally so thin that the peristaltic movements of the intestines may be more or less visible through them.

McMurrich in his description of the conjoined tendon in Piersol's Anatomy, describes that structure as follows:

> Owing to the oblique direction of the canal (inguinal), that portion of the aponeurosis of the external oblique which is strengthened by the intercolumnar fibres, together with a portion of the internal oblique, form its anterior wall; while its posterior wall is formed by the aponeurosis of the transversalis, together with the more medial lower portion of that of the internal oblique, these two layers of fascia (aponeurosis) uniting in this region to form what is termed the conjoined tendon, *which is attached to the body and superior ramus of the pubis*, and medially is especially thickened to form a band, the falx inguinalis, firmly attached along its medial border to the tendon of the rectus. More laterally, where it forms the medial boundary of the internal abdominal ring, it is also thickened, forming the ligament of Hesselbach (ligamentum interfoveolare). Between these two thickenings the abdominal wall is weaker and may give way to internal pressure, permitting a hernia, ... spoken of as direct hernia. (Fig. 1).

In two of the four cadavers examined the falx inguinalis (conjoined tendon) showed but little differentiation into three parts, and the so-called intermedial weak point was apparently as thick and strong as the lateral and medial parts. In one, there was evident thinning of the middle portion, while in the other there was marked differentiation into three parts, the middle portion being translucent and very deficient in the white fibers so noticable in the two first mentioned. In one cadaver also there was a difference between the two sides.

The four cadavers used for study were of middle age and moderately emaciated.

Barker (20) in his "Anatomical terminology," gives the BNA for the conjoined tendon as the falx (aponeurotica) inguinalis, which is to be considered the term for that structure in its entirety. Although this term was adopted by the Commission, it is evident that the conjoined tendon is not synonymous with the falx inguinalis.

It is certain that the conjoined tendon may consist of three parts, namely: the falx inguinalis, ligamentum interfoveolare and an intermediate thinner or attenuated portion which has not a definite name, and which I have called the pars intermedia.

Since a part cannot be equal to the whole it is evident that if the BNA term is to be perpetuated it should be considered synonymous with conjoined tendon, and considered as being made up of three parts, namely: the pars tendinea, attached by its medial border to the lateral edge of the rectus; ligamentum interfoveolare and the intermediate or weaker portion—the pars intermedia (fig. 1).

It is necessary to call attention to certain points in regard to the fascia transversalis which was first described by Sir Astley Cooper (4), and named by Cloquet (5), who in 1835 stated that the fascia transversalis in this region is sometimes composed of two aponeurotic laminae united at the posterior border of Poupart's ligament; the anterior arising from Poupart's ligament itself; the posterior being continuous with the fascia iliaca, which quits the iliacus internus muscle to be reflected upon the anterior parietes of the abdomen. These two laminae which ascend together between the transversalis and peritoneum, are easily separated on the outer side of the superior opening of the inguinal canal, but are intimately united around and on the inner side of this aperture. When these two layers are distinct, the posterior usually passes behind the rectus to the linea alba, but the ante-

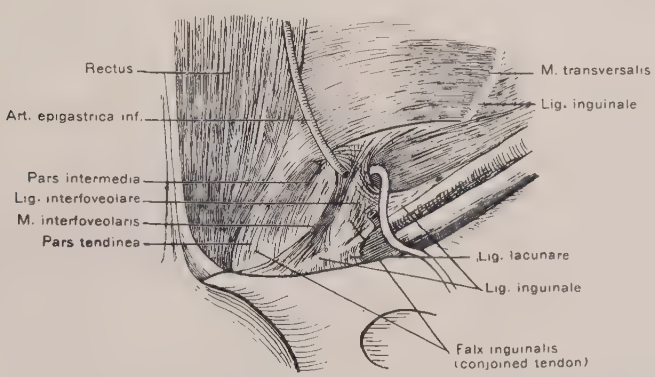

Fig. 1 Dissection of the posterior surface of anterior abdominal wall, showing relations of conjoined tendon and its expansions to internal abdominal ring (modified from Piersol).

rior is continuous with the outer edge of the rectus. The epigastric artery is found either in front or behind, and sometimes between the two layers. That these two layers are frequently met with is to be admitted.

The fascia transversalis is described by Piersol (21), Gray (22), Morris (23), and Cunningham (24) as lining the inner or deeper surface of the transversalis muscle. As a distinct structure it is directly continuous with fascia in the lumbar, diaphragmatic, inguinal, and pelvic regions and does not constitute the aponeurosis or tendon of the transversalis muscle as some authors have implied.

ANATOMICAL DISCUSSION

In discussing the anatomy of the inguinal region, Douglas states that "One may readily allow that the stronger the so-called thickened fascia transversalis of the groin, the less is any disposition to rupture present, but it must likewise be noted that if that structure be of unequal resisting power in different parts, such disposition to rupture is increased."

In preparations examined by him, he recognized the three parts of the conjoined tendon, their relative strength and position, and laid emphasis upon the ligamentum interfoveolare as the medial boundary of the abdominal ring. He also observed in certain specimens exhibiting herniae, in which the protrusion did not appear to be very long standing, that these bands or ligaments were specially well marked and he thinks that one may justly suppose that the tendency to rupture is increased when the inequality of resisting power is great between them and the rest of the tendon. Thus, in the case of oblique inguinal hernia, that if the medial boundary of the deep ring be especially strong, the outer limit of the opening will, with more readiness be separated from it when increased intra-abdominal pressure bears upon it, and so the deep ring will be opened up.

The medial boundary or pillar of the deep ring is a part of the transversalis tendon, and it becomes tense and resistant when drawn upon in the contraction of that muscle, and consequently this will slightly separate the two sides of the deep ring. Such a state is brought about when the body is flexed on the thighs, or vice versa; when in the erect position of the body the two sides of the rings are approximated. Therefore taxis for the reduction of hernia is most effective when the thighs are flexed.

In regard to direct inguinal hernia, he suggests that their production would be favored if the two bands alluded to were greatly stronger than the intervening tendon, and suggests that a fat hernia may be the cause of any inequality in the resisting power of the wall.

It is logical and in keeping with facts that the pars intermedia, which is the weakest part of the falx inguinalis should be the point to give way, and the tenseness of the pars tendinea and ligamentum interfoveolare would only guide the protruding part and at the same time intensify the weakness of the pars intermedia by directing pressure to it.

It is the intention to discuss the conditions leading up to the production of fatty inguinal or femoral herniae, only in so far as the direct form is concerned.

REPORT OF A CASE OF LIPOMA SIMULATING DIRECT INGUINAL HERNIA

The cadaver was that of a white male forty-nine years old. The lipoma was 30 mm. in length and 14 mm. in diameter, well-defined, lobulated and cylindrical in form and similar in color and gross structure to the fairly abundant adipose tissue present in the subperitoneal layer, with which it was directly continuous (fig. 2). It was firm from the hardening effects of the embalming fluids and attached by its base opposite to the center of Hesselbach's triangle, while its longitudinal axis was directed caudalward and lateralward toward the angle formed by the inferior epigastric artery and the inguinal ligament. The lipoma in its descent had pierced the facia transversalis and the contiguous aponeurotic portion of the transversalis muscle, both of which—especially the former—were very much thinned and scarcely traceable as distinct coverings. The remainder of the overlying falx inguinalis was also distinctly thinned but had not yielded. It is to be observed that the protrusion took place at the weakest point of the falx inguinalis (conjoined tendon) or at the pars intermedia. The apex of the lipoma emerged a little below the inferior border of the falx and at that point entered the connective tissue interval between the fascia cremasterica and the process infundibuliformis of the fascia transversalis. In other words it was located in the inguinal canal between two of the coverings of the spermatic cord, a little superior and lateral to the subcutaneous ring. There was no evidence of traction upon the peritoneum, which passed normally over the site of the growth. Neither was there any evidence of an abdominal cicatrix, indicating that an operation had ever been performed upon the anterior abdominal walls. The lipoma was easily pulled from its bed, there being no adhesions and the little finger could with slight pressure be passed into the cavity which it had occupied.

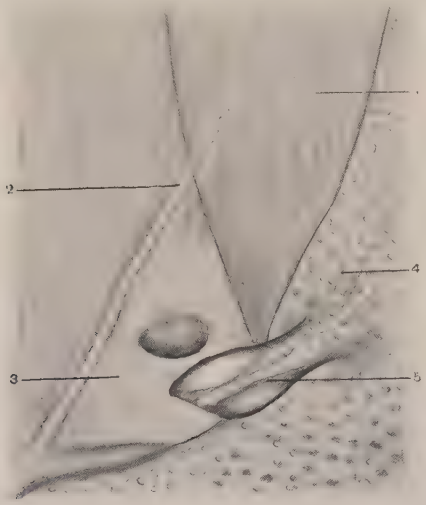

Fig. 2 Hesselbach's triangle viewed from behind, showing the fascia transversalis in situ, with lipoma and point of emergence. Natural size, reduced $\frac{1}{3}$. 1, rectus; 2, art. epigastrica inf.; 3, Hesselbach's triangle; 4, subperitoneal tissue reflected medially; 5, lipoma.

DISCUSSION OF CASES

A case reported by Douglas (17) corresponds very closely to the one reported above. The peritoneum was smooth, and on stripping it off a small mass of fat was attached to it, and lying just lateral to the pars tendinea of the falx inguinalis. It had projected into a deep fossa, which easily admitted the point of a finger, and passed medialward and caudalward ending at the subcutaneous ring.

Annandale (9) cites a case of a fatty mass projecting through the right subcutaneous ring. It proved to be a mass of subperitoneal fat, which had come down through the abdominal wall in the direction of a hernia, pushing before it the fascia transversalis, breaking through the fibers of the falx inguinalis, but forcing the external spermatic fascia in front of it. The peritoneum was quite smooth and free from depression. He cites another case—that of a male—in which a similar protrusion was present on each side and "both contained a peritoneal sac." From the literature it appears that the presence of a peritoneal sac is the rule, and Annandale (9) was the first to draw attention to the practical importance of recognizing and carefully examining these fat masses during operations for the relief of hernia.

For a fuller account of cases and the anatomical conditions, the reader should consult Hutchinson's (15) and Wernher's (10) papers. De Garmo (25) in his work on Abdominal Hernia, states that "Elongated pieces of fat occupying the canal (inguinal) and protruding at the external ring, with or without hernia, are extremely common." Most all the text-books on pathology and surgical pathology mention their frequency and the part they play in opening up the way for a future intestinal or omental protrusion. Hence although a lipoma may be small, it may nevertheless be a potential factor in bringing about conditions which could lead to error in diagnosis.

CONCLUSIONS

Douglas from his study of lipomata simulating direct inguinal herniae, surmised that the development in some cases is as follows:

1. "The formation of a hollow in the wall, the transversalis tendon in its weakest part yielding under the pressure of a mass of fat."
2. "The filling of this fossa by a peritoneal pouch."
3. "The entrance of intestine or other contents into the sac thus formed."

In the case reported there was no evidence of a hollow, for the tranversalis tendon was in its usual plane throughout. The protrusion was abruptly through the fascia transversalis and the only part of the transversalis tendon affected was that immediately over the protruded fat. From the study of the case I concluded that the giving way of the parts was sudden and that the contiguous subperitoneal tissue was immediately engaged in the break, for when the lipoma was examined, it could partly be spread out in continuity with the subperitoneal tissue and contained three small lobules of fat. The possibility of the protrusion ever having given any trouble was in all probability more or less remote. It appears that in this instance the cause of the lipomatous formation was a small rupture of the fascia transversalis and the contiguous deep lamina of the falx inguinalis, through severe straining as during the act of heavy lifting, during defecation or through a blow upon a tense abdomen. Although it is not improbable that the protrusion may have formed gradually in the development of the tumor. The anatomical structure of the falx inguinalis in this case was not carefully studied. The series of four cadavers and others that were carefully studied showed that the falx is subject to marked variation, in the relative thickness of the aponeuroses of the internal oblique and trasversalis muscles not only in different individuals, but in the same individual.

The aponeurosis of the transversalis is the chief factor in forming Hesselbach's ligament. The two aponeuroses vary in the degree to which they unite to form the falx inguinalis. In one of the cadavers examined the aponeurosis of the internal oblique and transversalis were quite separate down to the os pubis. The internal oblique played but little part in the formation of the falx, and was distinctly muscular over the triangle, while the aponeurosis of the transversalis was broadly composed of white fibrous tissue and exhibited the differentiation into the three parts already described.

LITERATURE CITED

(1) Morgani 1745 Cited from Douglas, Edin. Med. Jour., vol. 35, ii, 1889–90.

(2) Pelletan 1810 Cited from Douglas, Edin. Med. Jour., vol. 35, ii, 1889–90.

(3) Scarpa, Antoine 1823 Traité pratique des hernies. Traduit de L'Italien per M. Cayol, Paris.

(4) Cooper, Sir Astley P. 1804 and 1827 The anatomy and surgical treatment of inguinal and congenital hernia. London, 1804; also 2 pts., 2 ed. by Aston Key, X, 79 pp. 17 pl., ii. l. fol., London.

(5) Cloquet, M. Jules 1835 Anatomical description of the parts concerned in inguinal and femoral hernia. London, Translated from the French by A. M. McWhinnie.

(6) Maunder, C. F, 1864 Lipoma in the inguinal region, simulating hernia. London Hosp. Reports, vol. i, p. 121.

(7) Paget, J. 1865 Lectures on surgical pathology, pp. 396–402.

(8) Gascoyen, Geo. G. 1865–66 Fatty tumors in the scrotum. Pathol. Socs. Trans., vol. 17, p. 176.

(9) Annandale, Thomas 1870 On fatty hernia. Edin. Med. Jour., ii, January, June, p. 769.
1868 Notes on tumours. Brit. Med. Jour., vol. 1, p. 162.

(10) Wernher, 1869 Von Den Fettbrüchen und den bruchähnlichen Fettgeschwülsten. Virchows Archives, Bd. 47, p. 178.

(11) Gay, John 1872 Case of Enteritic obstruction with a rare form of femoral hernia. Pathol. Trans., London, p. 95.

(12) Butlin, H. T. 1874–75 Fatty tumour removed from the inguinal canal during the operation for hernia. Pathol. Socs. Trans., vol. 26, p. 186.

(13) Tillaux, P. 1879 Traite D'Anatomie Topographique avec applications a la Chirurgie. Paris, vol. 2. pp. 619–663.

(14) Stonham, C. 1886 Lipoma of the spermatic cord (Note). Trans. Pathol. Soc., London, vol. 37. pp. 341–458.

(15) Hutchinson, Jonathan, Jr. 1886 Lipomata in hernial regions. Trans. Pathol. Soc., London, vol. 37, pp. 451–458.

(16) Broca, A. 1888 Études sur les lipomes inguineaux et les hernies inguinales. Paris.

(17) Douglas, Kenneth M. 1889–90 Fat herniae in the inguinal region. Edin. Med. Jour., vol. 35, ii, pp. 918–921; also Tr. Med. Chir. Soc. Edin., NS ix, pp. 83–89.

(18) Imbert, Leon 1897 Un cas de lipocéle inguinal. Bull. Soc. Anat. de Paris, T. 72.

(19) Shattock, S. G. 1908–09 On normal tumor-like formations of fat in man and the lower animals. Proc. Roy. Soc. Med., London, ii, Pathol. Section, pp. 207–270.

(20) Barker, L. F. 1907 Anatomical terminology.

(21) Piersol, G. A. 1907 Human anatomy.

(22) Gray, Henry 1908 Anatomy, descriptive and surgical; 17th edition.

(23) Morris, Henry, and McMurrich, J. P. 1907 Human anatomy; 4th edition.

(24) Cunningham, D. J. 1906 Text-book of anatomy; 2d. edition.

(25) De Garmo, W. B. 1907 Abdominal hernia.

(26) Lawrence, Wm. 1843 A treatise on ruptures; 2d edition, XIII, 484 pp., 2 pl., 1810. The same from the 5th edition. London Ed. XVI, pp. 18–480.

(27) Quain, R. 1855 Some unusual circumstances met with in operations for the relief of strangulated hernia. Med. Times and Gazette. January 6, p. 4.

(28) Spalteholz, Werner 1901 Handatlas der Anatomie des Menschen.

THE DEVELOPMENT OF THE PULMONARY VEIN IN THE DOMESTIC CAT

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NINE FIGURES[1]

A review of the literature concerning the pulmonary vein reveals the fact that the various investigators have been divided into two groups according to their method of dealing with the subject. On the one hand the older writers, such as Reisseisen (1), Sömmering (2), Zuckerkandl (3) and J. F. Meckel (4) regarded the vein simply as part of the general vascular complex and consequently described its morphology with relation both to other portions of the pulmonary system and to the systemic circulation. The later investigators, as Schmidt (16), His (17), Born (18), Röse (19) and Fedorow (22) have studied the morphology of the vein as such, without reference to its relation to or possible connection with, the extrapulmonary vascular system. They have thus not defined the proper position of the vein in the vascular complex.

The first important contributions were those of Reisseisen (1) and Sömmering (2). They established the fact that the bronchial and pulmonary veins communicate freely within the lung and that the bronchial veins empty, either directly or through subordinate branches, into the azygos and hemiazygos veins and thus into the systemic circulation.

J. F. Meckel (4) accepted the results of Reisseisen and Sömmering, and further noted instances in which the pulmonary veins communicate through large or small radicles with the systemic circulation. He states:

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[1] Expense of illustrations borne by author.

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> Höchst merkwürdig ist es, dass nicht bloss in diesem feinen Gefässnetze (i.e. on the surface of the lung), sondern auch zwischen den grösseren Zweigen und Ästen der Lungen- und Luftröhrengefässe bedeutende Anastomosen Statt finden.
>
> Die Bronchialvenen senken sich sogar grösstentheils in die Lungenblutadern, nur die an der Wurzel der Lungen befindlichen treten zu kleinen Stämmen zusammen, welche sich in die unpaarige Vene oder die obere Hohlader, oder untergeordnete Äste des Körpervenensystems einsenken.
>
> Aus dieser Anordnung ergibt sich daher: 1. dass auch im normalen Zustande in den Lungen sehr bedeutende Communicationen zwischen dem Systeme des rothen und dem des schwarzen Blutes Statt finden; 2. dass die als Abweichungen bisweilen erscheinenden, wo grössere Gefässe der entgegensetzten Systeme sich auf dieselbe Weise verhalten, z. B. die Kranzblutadern des Herzens sich in die linke Vorkammer, eine oder mehrere Lungenvenen in die Hohlvene einsenken, eine grosse überzählige Lungenpulsader von der abstiegenden Aorta entsprang u.s.w., nur weitere Entwicklungen dieses Typus sind, und 3. die wichtige Bemerkung, dass diese Anastomosen in den Fällen, wo die Lungenpulsader verschlossen oder beträchtlich verengt war, und dennoch das Leben bedeutend hoch gebracht wurde, höchst warhscheinlich die Wege sind, durch deren Erweiterung das Blut in die Lungenpulsadern geführt wurde.
>
> In der That werden auch unter dieser Bedingung die Luftröhrenäste erweitert gefunden.

Many other authors, among them Hyrtl (5), Gegenbauer (6), Krause (7), Winslow (8), Böhmer (9), M. J. Weber (10), Arnold (11), and W. Gruber (12) note connections between the veins of the pulmonary and systemic circulations and describe them as anomalies or variations.

Zuckerkandl (3) was the first to undertake the study of these problems. In a careful and masterly paper he both added to our knowledge of the pulmono-systemic anastomoses and attempted to account for and interpret the origin of the system as a whole by reasoning from his findings in the infant and adult. His work was carried out for the most part on the bodies of children which had been injected through the pulmonary vein with a thin colored injection mass. He found that the mass fills not only the pulmonary veins, but also the bronchial veins and through them the azygos, hemiazygos and mediastinal network of veins and in many cases reaches even the postcava and the gastric veins. The anastomoses between the pulmonary and systemic veins vary in size in different individuals, and within small limits vary in position, but the pulmonary veins regularly anastomose with the veins of the mediastinal network. He concludes, therefore, that the anomalies cited are caused by a local overgrowth of a capillary plexus in one position with a corresponding underdevelopment at the point where the vein in question should normally develop. In this manner he reasons that probably the pulmonary and systemic veins are merely remnants of an originally great indifferent plexus of capillaries from which lines of drainage have been developed as best suited to the functions of the part.

Subsequent to the work of Zuckerkandl attention appears to have been confined mainly to the consideration of the pulmonary vein itself, and especially to the relation of its opening into the heart in the various stages of its development.

Boas (13), Goette (14), and Hochstetter (15) describe the opening of the pulmonary vein into the auricle in the dipnoean, amphibian and reptile. Boas divides the sinus venosus into two portions. The left, which is the smaller receives the opening of the pulmonary vein. How it subsequently reaches its final position in the left auricle he does not definitely demonstrate. Goette considers that the vein first grows out from the sinus venosus, is then cut off from this and finally establishes its definitive orifice in the left auricle. Hochstetter merely states that the pulmonary vein opens first into the sinus venosus and subsequently in the left auricle.

Schmidt (16) studies the opening of the pulmonary vein in the pig embryo. In the embryo of 7 mm. he describes the vein as passing ventrally through the dorsal mesocardium to empty into the left portion of the sinus venosus, which is situated to the left of the common opening of the pre- and postcardinal veins. He then describes the absorption of the proximal segment of the vein into the auricular wall with the subsequent inclusion of its tributaries until four separate pulmonary veins empty into the auricle. The description of the opening of the vein in the left portion of the sinus venosus in the pig at this stage agrees with the conditions found in the cat embryo of a slightly earlier stage, that is, 5 to 6 mm.

His (17) demonstrates the pulmonary vein as opening into the left portion of the sinus venosus in an early stage in the human embryo. The opening is situated to the left of the left valve of the sinus. The shift of position of the opening to its definitive site is the result of the progression of this valve to the left to join the lower portion of the septum superius on the posterior wall of the auricle.

Born (18), Röse (19), and Narath (20) describe the vein as opening into the auricle but do not consider the early stages in detail.

Flint (20) devotes the major part of his attention to the pulmonary arteries and bronchi and mentions the pulmonary vein only in passing. In the 5 mm. pig embryo he notes the presence of a plexus around the esophagus and describes the pulmonary vein as growing out from the sinus venosus. He states that from the sinus it passes dorsad in the dorsal mesocardium to the pulmonary anlage which at this stage is only partially separated from the esophagus. The venous radicles anastomose with the capillary plexus around the esophagus and pulmonary anlage thus forming a direct line of communication which leads from the ventral aspect of the pulmonary anlage to the dorsal wall of the sinus venosus. He makes no attempt to define the limitations of the plexus which he notes around the esophagus and consequently fails to recognize that it is only a part of a rich plexus which is present throughout the entire length of the gut and communicates freely with the adjacent systemic veins thus serving as a groundwork for future drainage lines between the respiratory and systemic circulations. His statement that the pulmonary vein grows out from the sinus venosus is not substantiated by any detailed evidence, nor does he explain the method by which this vein joins with the plexus around the pulmonary anlage.

Fedorow (22) describes the development of the pulmonary vein in the amphibian, reptile, bird and mammal and concludes that the vein is an outgrowth of the dorsal wall of the sinus venosus at a point situated to the left of and above the opening of the cornua of the sinus. This opinion he bases on the fact that in the posterior wall of the sinus, not far from the auricle, he observed a proliferation of endothelium which projects into the dorsal mesocardium. Into this the cavity of the sinus tunnels and forms a single trunk which, a short distance from the sinus, gives off branches. These at a later stage, join with the capillaries of the pulmonary anlage and thus complete the pulmonary vein. The subsequent behavior of the venous opening he describes as follows:

> 1. Der Teil des Sinus venosus, in den die Lungenvene einmündet, wird infolge des ungleichen Wachstums verschiedener Abschnitte der Herzwand in die Vorkammerwand mit aufgenommen. Auf diese Weise fliesst jetzt die Vene in den gemeinsamen Teil der Vorkammer ein, d.h. mehr kranial als sie früher einmündete.
> 2. Die weite Sinusmündung verengt sich, indem eine besondere Falte der Herzwand an der Grenze zwischen dem Sinus und der linken Vorkammer von links nach rechts rückend nach innen einwächst; diese Falte nenne ich den "Vorkammerboden." Die Venenmündung bleibt dabei kranial vom Vorkammerboden liegen.
> 3. Indem die Vorkammerscheidewand allmählich höher wird und mit ihrer Insertion einen immer grösseren Teil der Vorkammerwand einnimmt, erreicht sie die Venenmündung und lässt früher oder später dieselbe links von sich liegen; dann wächst die Scheidewand mit dem Vorkammerboden zusammen und die Venenmündung wird jetzt der linken Vorkammer gehören.

The above description of the course of the orifice of the vein as it passes to its definitive position in the left auricle immediately raises the question whether the 'Vorkammerboden' which he describes is other than the left valve of the sinus venosus. If it is the left valve of the sinus his description of its shift to the left to fuse with the lower portion of the septum superius corresponds with that of His.

v. Möllendorf (23) disagrees with the findings of Goette and Fedorow as to the sprouting of the pulmonary vein from the sinus venosus. He considers that the vein is connected from the first with the capillary plexus around the pulmonary anlage and with the sinus venosus. He does not concern himself with the formation of the final opening of the vein into the left auricle, nor does he recognize the connection of the capillaries around the pulmonary anlage with those of the surrounding systemic vascular system. He further differs from all other observers in that he states that from the first there are two pulmonary veins which empty into the sinus venosus by separate orifices.

From the foregoing review of the literature it will be seen that our knowledge of the morphology of the pulmonary vein is incomplete in two main points, namely, (1) The anlage of the vein and its connection with the sinus venosus has not been described in detail; and (2) the method by which the vein changes its orifice in the center of the sinus venosus for one in that portion of the sinus which lies to the left of the left sinus valve has not been considered. In addition, the general relation which the pulmonary venous system bears to the systemic has been entirely neglected in the study of the embryology of the vein.

It is the purpose of the present paper to follow the development of the pulmonary vein of the domestic cat from the early stage in which it empties into the cephalic portion of the sinus venosus in the median line to the stage in which it attains its definitive connection with the left auricle. At the same time, its relation to the systemic circulation will be considered from the standpoint of the drainage lines which exist normally in the infant and adult as shown by Zuckerkandl, enlargement of which gives rise to the so-called anomalies.

The material used in this investigation consisted of embryos of the domestic cat in the embryological collection of the Department of Anatomy of Columbia University. These were imbedded in paraffin, for the most part sectioned at 13.32μ and stained with hematoxylin (Delafield) and Orange G after the method of Morris (24). A few of the smaller embryos were stained in toto with borax carmine before being imbedded and sectioned. The embryos studied ranged in size from 4.5 mm. to 7 mm. When deemed necessary reconstructions were made by the method of Born.

The complete list of embryos studied is as follows:

Nos. 82, 93, 134, 469, 4.5 mm. in length.

No. 226, 5 mm. in length.

Nos. 103, 110, 5.5 mm. in length.

Nos. 84, 85, 109, 115, 116, 117, 128, 187, 283, 481, 482, 6 mm. in length.

Nos. 129, 130, 131, 186, 261, 6.5 mm. in length.

Nos. 105, 108, 119, 121, 135, 137, 138, 266, 281, 487, 488, 7 mm. in length.

In addition, the process of development as outlined below has been substantiated by observation made upon the embryos of the chick in the Columbia collection, and the presence of the plexus around the esophagus and pulmonary anlage and its connection with the surrounding systemic veins has been observed by A. M. Miller[2] in connection with the developing blood cells in the mesenchyme of the chick.

The development of the vein, so far as it will be considered in this paper, may be divided conveniently into three stages according to the point of entrance of the vein into the venous portion of the heart, namely, (1) a stage in which the vein empties into the cephalic portion of the sinus venosus in the median line, (2) in which it empties into the sinus venosus to the left of the left sinus valve, and (3) in which it empties into the left auricle.

1. *First stage: embryos of 4.5 mm. (figs. 1 and 2)*

The heart consists of a single tube so twisted upon itself that the ventricular portion lies ventrad and caudad and the auricular portion dorsad and cephalad. At the dorso-cephalic extremity of the auricle the ducts of Cuvier unite to form the sinus venosus. Dorsal to and at a level slightly cephalad of the sinus venosus, the tracheal furrow on the ventral aspect of the gut ends in a slight dilatation, the pulmonary anlage. In the mesenchyme surrounding the intestinal tract throughout its entire length are many capillaries. For the most part these have formed a netlike plexus which anastomoses freely with the adjacent veins of the systemic circulation. In some places the plexus is incomplete and is represented by unconnected venous spaces, the anlages of capillaries. The anastomoses with the surrounding veins may be divided into

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[2] Personal communication.

cephalic and caudal groups; the cephalic group communicates with the capillaries around the aorta and with the precardinal and segmental veins and the caudal with the omphalo-mesenteric and postcardinal veins. The irregular network already shows a tendency to the formation of longitudinal drainage lines along the lateral and dorsal aspects of the intestine. The plexus will be designated the 'splanchnic plexus' (fig. 1, *10*).

In addition to the communications with the systemic veins noted above, the splanchnic plexus exhibits two well defined connections with the venous portion of the heart, (1) the cephalic or pulmonary, and (2) the caudal or postcaval. These are constant both in occurrence and position.

1. The pulmonary tap. In the region of the tracheal furrow the plexus is pushed forward by the projection of the furrow from the remainder of the intestinal tube. At its caudal extremity the plexus is very abundant, forms a network surrounding the pulmonary anlage and on the sides of the anlage the capillaries show a tendency to coalesce to form a longitudinal vein. At the ventral pole of the lung bud a common stem formed by the fusion of the capillaries of the two sides passes ventrad and slightly caudad through the dorsal mesocardium to open by a rounded orifice into the cephalic aspect of the sinus venosus in the median line, at a level cephalad of and between the ducts of Cuvier.

2. The postcaval tap. This is found caudal to the pulmonary anlage at the level at which the sinusoids of the liver are forming. It (figs. 1 and 2, *13*) is formed by the junction of radicles of the lateral longitudinal lines of the splanchnic plexus which join in the median line at the cephalic limit of the liver, fuse into a single vessel which passes cephalad through the dorsal mesocardium and enters the caudal portion of the sinus venosus in the median line between the omphalo-mesenteric veins at a point opposite the opening of the vein from the pulmonary anlage. The caudal and cephalic taps are connected along the sides of the esophagus by the lateral longitudinal drainage lines before-mentioned.

At this stage the pulmonary vein exists as a single vessel having two main vascular connections, namely, (1) ventrally a single rounded orifice in the sinus venosus, and (2), dorsally a connection with that portion of the splanchnic plexus which is pushed forward by the growing pulmonary anlage, which it joins at the ventral pole of the lung bud. If the possible routes of blood flow from the pulmonary anlage be considered it will readily be seen that aside from the main channel through which the blood is returned to the heart, there exist many subsidiary paths by which the blood may reach the systemic circulation. The connections with the pre- and postcardinal veins are the most important of these as they map out the future channels to the hemiazygos and azygos veins and thus in the adult form the bronchial veins.

This rich plexiform network of the splanchnic plexus with its abundant inosculation with surrounding vessels explains the various anomalies of the pulmonary veins heretofore described, and explains also the normal communications which, as pointed out by Zuckerkandl, exist between the pulmonary, systemic and portal systems. In fact, the presence of this plexus with its communications with the heart through the pulmonary vein and with the systemic and portal systems through its connection with surrounding mediastinal veins fulfils the requirements of Zuckerkandl, who states:

> Dieser Anastomosencomplex der Lungenvenen würde sich leicht erklären, wenn bekannt wäre, welcher Art das Gefäss-system der primären Anlage ist und wie sich aus demselben das respiratorische Netz entwickelt. Leider ist die Entwicklungsgeschichte noch nicht im Stande, hierauf eine genügende Antwort zu geben. . . . . Über das Verhalten der Blutgefässe zur primären Anlage der Lunge, so wie auch über die Entwicklung der Lungenvenen, desgleichen darüber, wie sich diese verschiedenen Gefässbezirke einerseits zu einander stellen und andererseits ob und in welcher Weise die theilweise Rückbildung der primären Gefässen erfolgt, liegen keine bestimmten Untersuchungen vor. Bei genauerer Kenntniss der Entwicklungsgeschichte wird sich wahrscheinlich ergeben, dass die Verbindungen der Lungengefässe mit den bronchialen und mediastinalen, insbesondere aber die der letzteren bloss Reste von reichlichen Anastomosen sind, die vorher zwischen Lungen- und Körpervenen bestanden haben. Wenn dem so ist, wenn die Verbindungen Rest von reichlichen Anastomosen sind, so ist die Variabilität in Bezug auf Localität und Stärke der Anastomosen leicht erklärt.

Second stage: embryos of 5 to 6 mm. (figs. 3 and 4)

The most important change from the preceding stage is noted in the shift in position of the sinus venosus in its relation to the auricle. The sinus has moved caudad and to the right and now empties into the caudal and right portion of the still undivided auricle. The right duct of Cuvier (fig. 4, *7*) is very short and extends dorso-ventrally to empty into the right cornu of the sinus which is situated furthest to the right. The left duct of Cuvier (fig. 4, *8*) formed by the junction of the left pre- and postcardinal veins, curves caudally and to the right to empty into the left cornu which then passes horizontally to the right and joins the caudal and left portion of the right cornu. The two cornua then open into the sinus by a common orifice (fig. 4, *9*). The right limit of the sinus is well defined by a reduplication of the myocardium which projects ventrad and mesad into the cavity of the auricle as a vertical fold having a ventral free margin. This fold forms the right sinus valve. It is triangular in shape with the apex of the triangle directed upward and forward and continuous on the roof of the auricle with the septum spurium. The dorsal and caudal edges are continuous with the dorsal and caudal walls of the auricle. The left limit of the sinus venosus is hard to define as it shades gradually into the wall of the auricle. The left margin of the common opening of the cornua presents a very slight reduplication of the myocardium ventrad, the anlage of the left sinus valve. On the roof of the auricle in the median line the septum superius projects downward presenting a free edge below. The dorsal limit of this septum blends with the dorsal wall of the auricle at a point to the left of and cephalad to the upper limit of the left valve of the sinus. Between the left valve of the sinus and the septum superius at a level caudal to the dorsal limit of the latter is the opening of the cephalic tap of the splanchnic plexus, the pulmonary vein. This is situated just to the right of the median line (fig. 4, *11*). The caudal tap of the splanchnic plexus enters the caudal aspect of the right cornu of the sinus on the left side just previous to its junction with the left cornu.

The pulmonary anlage (fig. 3, *2a*) is represented by a retort shaped prolongation arising from the ventral aspect of the gut at the level of the upper limit of the auricle. This extends caudad and slightly ventrad to the level of the sinus venosus. Along either side of this tube is a plexus of capillaries which at the ventral pole of the anlage forms a definite vein which passes ventrad through the dorsal mesocardium. Just dorsal to the sinus venosus (fig. 3, *11*), the two veins join to form a common trunk which after a short ventrad course meets the dorsal wall of the sinus venosus and passes through it as a long funnel shaped tap to empty by the orifice described above. Cephalad the pulmonary plexus communicates with the lateral longitudinal line of the splanchnic plexus on either side.

The caudal tap (fig. 3, *12*) has become a well marked vein which passes cephalad just to the right of the median line to the level of the lower limit of the sinus venosus. At this point it bends sharply to the right and passes through the dorsal mesocardium behind the dorsal wall of the sinus venosus to empty into the left caudal aspect of the right cornu of the sinus as described above. The connection of this vein dorsally with the left longitudinal line of the splanchnic plexus is represented only by a capillary plexus which communicates freely with the sinusoids of the liver. Above the level of the upper surface of the liver, between it and the pulmonary plexus the lateral lines of the splanchnic plexus form a plexus surrounding the esophagus which communicates above with the pulmonary plexus and below with the sinusoids of the liver and through these with the postcaval tap. On the right side the caudal tap of the plexus is well formed below the level of its orifice into the sinus venosus and can now be recognized as the anlage of the hepatic and suprahepatic portions of the postcava.

From the above it is clear that the change in relation of the orifices of the veins opening into the sinus venosus is the result of unequal growth in the various portions of the sinus. The opening of the pulmonary vein has followed the caudal progression of the sinus and as the growth of the two sides has been equal at this level the orifice retains its original median position in the sinus. Caudal to this level growth has been markedly unequal on the two sides, the left increasing in width much more rapidly than the right. As a result, the lower portion of the sinus has shifted to the right side and now opens into the caudal and right aspect of the auricle. The evidence going to prove this inequality of growth is two-fold, (1) The left duct of Cuvier and the left cornu of the sinus are long drawn out and pursue a lateral course from above downward and from left to right, while the right duct of Cuvier and the right cornu are short and pursue a dorso-ventral direction; (2) The caudal tap of the splanchnic plexus ascends in the dorsal mesocardium to the level of the lower limit of the sinus venosus, then bends sharply to the right and pursues a horizontal course behind the sinus until it reaches its entrance into the right cornu just before the fusion of the latter with the left to form a common orifice. Referring to the previous stage, the relative position of the orifice into the sinus has changed but little, the point of entrance still representing the original median line of the sinus which has disappeared through the fusion of the two cornua. The horizontal course through the dorsal mesocardium behind the sinus represents the amount of growth of the left portion of the auricular wall over that of the right.

The plexus around the pulmonary anlage still retains its lines of venous drainage, the pulmonary vein draining into the systemic circulation by means of the connections of the pulmonary plexus with the cephalic portions of the lateral longitudinal lines. Below the pulmonary plexus communicates with the caudal tap by means of the esophageal plexus which represents the lateral and posterior longitudinal lines of the splanchnic plexus. In addition to these communications the well known broncho-pulmonary anastomoses in the lung bud itself are easily recognized.

Third stage: Embryos of 6.5 to 7 mm. (figs. 5 and 6)

The sinus venosus with the exception of the openings of the cornua has been incorporated into the auricle. The right valve of the sinus (fig. 6, *40*) is very prominent and above is continued into the septum spurium which has shifted to the left and fused with the septum superius. The left valve of the sinus has likewise shifted to the left and its cephalic extremity on the dorsal wall of the auricle has fused with the dorso-caudal portion of the septum superius. As a result of the latter shift the orifice of the pulmonary vein has preceded the left valve of the sinus, passed under the septum superius, and now empties into the left auricle having both septum superius and left valve of the sinus, or in other words, the interauricular septum on its right (fig. 6, *11*).

The pulmonary anlage shows a division into two lateral tubular prolongations, the anlages of the bronchi, which are surrounded by a rich capillary plexus. From the ventro-caudal aspect of each of these plexuses a well marked channel passes caudo-ventrally to unite with its fellow of the opposite side, and, after a very short course in the dorsal mesocardium, enters the wall of the left auricle, passes through it by a long funnel shaped tap and empties into the auricle by the orifice described above. From the dorso-cephalic portion of the pulmonary plexus of either side small vessels extend cephalad and dorsad to empty into the lateral longitudinal lines of the splanchnic plexus, thus mapping out the course of the future bronchial veins to the azygos and hemiazygos veins. The caudal tap of the splanchnic plexus is now a well marked vein which lies on the right side of the median line, receives the hepatic sinusoids and is plainly recognizable as the pars hepatica and suprahepatica of the postcava. The paths of communication between the pulmonary plexus above and caudal tap of the plexus below remain as many small anastomoses between the pulmonary capillaries above with the adjacent systemic veins and the communications of the latter with the postcaval tap below the septum transversum. The broncho-pulmonary anastomoses in the lung bud itself are still present.

The orifice of the pulmonary vein has now, by the fusion of the left sinus valve with the septum superius, been transferred to the left auricle. The two subsidiary lines of drainage described in the previous stages are retained, but in markedly different degrees. That from the pulmonary plexus to the cephalic portion of the lateral longitudinal lines consists of several well marked channels which map out the future course of the bronchial veins. The caudal line of drainage to the postcava exists now only as small capillary anastomoses between pulmonary plexus on the one hand and the esophageal and aortic plexuses on the other, thus accounting for the irregularity of the connections between pulmonary and mediastinal veins and through the latter with the portal and postcaval systems described by Zuckerkandl.

Summary. It is thus seen that the common pulmonary vein develops from the cephalic communication between the splanchnic plexus and the sinus venosus. The plexus is pushed forward by the developing lung bud and is carried ventrad and caudad as the pulmonary anlage develops. With the displacement of the sinus venosus caudad and to the right due to the inequality of growth of the two halves of the sinus and auricle, the pulmonary orifice moves only slightly to the right and empties into the left portion of the sinus, to the left of the left sinus valve and at a level below the septum superius. The formation of the interauricular septum by fusion of the left sinus valve with the dorsocaudal extremity of the septum superius definitely assigns the pulmonary vein to the left auricle.

The plexus around the lung bud is differentiated into two systems, (1) from its ventral and caudal portion, the pulmonary for the fulfillment of the respiratory function, and (2) from the caudal and cephalic portion the bronchial for the venous drainage of the lung tissue proper. This is diametrically opposed to the opinion of Fedorow who states that he cannot accept the view of an originally indifferent plexus of capillaries which may develop on the one hand into veins and on the other inosculate with arteries, but believes that the vein grows directly from the dorsal wall of the sinus venosus as a bud finally to inosculate, after dividing into countless branches, with the plexus around the pulmonary anlage, while the artery approaches the opposite extremity of the plexus growing in a similar manner from the sixth aortic arch.

That portion of the splanchnic plexus lying between the pulmonary anlage cephalad and the hepatic sinusoids caudad serves as a temporary direct communication between the pulmonary vessels and the systemic circulation represented by the postcaval tap of the splanchnic plexus. The paths by which this circulation is carried out have already been described. With the further development of the pulmonary veins this portion of the splanchnic plexus loses its connection with the pulmonary capillaries except for the persistence of occasional small veins which pass from the pulmonary capillaries to the esophageal or aortic plexuses, thus mapping out the communication of the pulmonary veins with the postcaval and portal systems through the veins of the posterior mediastinum.

This conception of the pulmonary system, namely, that it is simply a specially developed part of an indifferent plexus originally present in this region, assigns to the vein its proper position in the general vascular complex. It also serves to explain the small communications between pulmonic and systemic circulations normally present in the adult and the large channels occasionally found which are classed as anomalies of the pulmonary veins.

An anomaly of the right pulmonary vein

A specimen of most unusual abnormality of the right pulmonary vein which bears out the conception of the development of the pulmonary system as given above was presented to the Anatomical Department of Columbia University by Dr. Edwards A. Park. Although previously published (25) with a short and incomplete note as to the probable etiology of the anomaly, a brief description will be given here.

On ventral view (fig. 7) the heart was normal save for a small teat-like process attached to the tip of the left auricular appendage. The dorsal view (fig. 8) showed complete absence of any right pulmonary vein entering the left auricle. The right lung was very small and compressed against the inner wall of the thorax by the heart which in turn was pushed to the left by a very large left lung. In the main interlobar fissure of the right lung was a good sized venous channel, the pulmonary vein which, beginning in the region of the hilum ran caudad to the diaphragm, pierced it, and on reaching its abdominal surface turned sharply to the left to enter the right aspect of the postcava in its course between liver and diaphragm (fig. 9).

The vein in this instance is a persistence, on the right side, of the lateral line of communication between the cephalic and caudal taps of the splanchnic plexus (fig. 3, *14*) accompanied by a loss of the normal communication between the plexus on the right side of the pulmonary anlage and the common stem of the pulmonary vein. The anomaly is unusual because of the entire absence of the normal entrance of the right pulmonary vein into the left auricle, the entrance of the pulmonary vein into the postcava representing merely the enlargement of a very small channel which is frequently present in the adult mammal.

LITERATURE CITED

(1) Reisseisen, F. D. 1808 Über den Bau der Lungen. Berlin, 1808 u. 1822.

(2) Sömmering, Th. 1808 Über die Struktur, die Verrichtung und den Gebrauch der Lungen. Berlin.

(3) Zuckerkandl, E. 1881 Über die Anastomosen der Venae pulmonales mit den Bronchialvenen und mit dem mediastinalen Venennetze. Sitzungsberichte der kaiserlichen Akad. der Wissenschaften. 84 Band. I Heft. Dritte Abtheilung. Juni.

(4) Meckel, J. F. 1820 Handb. d. mensch. Anat., Bd. 4, Halle u. Berlin.

(5) Hyrtl, J. 1880 Anatomische Variatäten. Hannover.

(6) Gegenbauer, C. 1880 Morph. Jahrb., Bd. 6. Leipzig.

(7) Krause, W. 1876 Variatäten der Körpervenen in Henle's Handb. der Gefässlehre. Braunschweig.

(8) Winslow, J. B. 1868 Cited in J. Arnold's essay: Ein Fall von Cor Triloculare, etc. Virch. Arch. Berlin.

(9) Böhmer, P. A. 1770 Hist. de l'Anat. et de la Chirug. Tom. 5, Paris.

(10) Weber, M. J. 1829 Über die Varietäten der Venen. Meckel's Arch. Leipzig.

(11) Arnold, F. 1850 Handb. d. Anat. des Menschen. Bd. 2, Freiburg im Breisgau.

(12) Gruber, W. 1876 Ein Fall von Einmündung der Vena pulmonalis dextra superior in die Cava superior. Virchow's Arch., Bd. 68, Berlin.

(13) Boas, J. E. V. 1880 Über Herz und Arterienbogen bei Ceratodus und Protopterus. Morph. Jahrb., Bd. 6.

1883 Beiträge zur Angeiologie der Amphibien. Morph. Jahrb. Bd. 8.

(14) Goette, A. 1875 Die Entwickelungsgeschichte der Unke (Bombinator igneus) als Grundlage einer vergleichenden Morphologie der Wirbeltiere. Leipzig.

(15) Hochstetter, F. 1903 Die Entwickelung des Blutgefässsystems. Hertwig's Handb. der Entwickelungslehre der Wirbeltiere. Bd. 3, T. 2, 4 Kap.

1908 Beiträge zur Entwickelungsgeschichte der europaischen Sumpfschildkröte (Emys lutaria marsili). 2. Die ersten Entwickelungsstadien der Lungen und die Bildung der sogenannten Nebengekröse. Denkschr. d. kais. Akad. d. Wiss. Wien 84.

(16) Schmidt, F. T. 1870 Bidtrag til Kundskaben om Hjerteb Undviklungshistorie. Nordiskt medic. Arkiv. Vol. 2. Nr. 23. 1870. Deutsches Referat von P. L. Panum im Jahresberichte über die Leistungen und Fortschritte in der gesammten Medizin von Virchow und Hirsch, 5, Bd. 1.

(17) His, W. 1885 Anatomie menschlicher Embryonen. T. 3, Leipzig.

1887 Zur Bildungsgeschichte der Lungen beim menschlichen Embryo. Arch. f. Anat. u. Phys. Abt. f. Anat.

(18) Born, G. 1889 Beiträge zur Entwickelungsgeschichte des Säugetierherzens. Arch. fur mikr. Anat., Bd. 33.

(19) Röse, C. 1888 Beiträge zur Entwickelungsgeschichte des Herzens. Inaug. Dissert. Heidelberg.

1889 Zur Entwickelungsgeschichte des Säugetierherzens. Morph. Jahrb., Bd. 15.

1890 Beiträge zur vergleichenden Anat. des Herzens der Wirbeltiere. Morph. Jahrb., Bd. 16.

(20) Narath, A. 1901 Der Bronchialbaum der Säugetiere und des Menschen. Bibliotheca medica. Abt. A. H. 3.

(21) Flint, J. M. 1907 The development of the lungs. Amer. Jour. Anat., vol. 6, no. 1.

(22) Fedorow, V. 1910 Über die Entwickelung der Lungenvene. Anat. Hefte. 1 Abt. 122 Heft (40 Bd., H. 3.).

(23) v. Möllendorf, W. 1912 Über Anlage und Ausbildung des Kiemenlungenkreislaufs bei Anuren (Bombinator pachypus). Anat. Hefte, Heft 141 (47 Band).

(24) Morris, J. T. 1909 A note on orange G counter-staining suggesting a useful method in the management of embryonic tissue. Anat. Rec. vol. 3, no. 12, December.

(25) Park, E. A. 1912 Proceedings of the New York Pathological Society, New Series, vol. 12, nos. 3 and 4, p. 88, March and April.

PLATE 1[3]

EXPLANATION OF FIGURE

1 Schema of the left side of a wax reconstruction of a 4.5 mm. cat embryo. Columbia collection no. 134, × 200. The left cornu of the sinus venosus together with the structures entering it, has been removed.

2, gut
2a, pulmonary anlage
4, left postcardinal vein
6, left precardinal vein
8, left duct of Cuvier
9, sinus venosus
10, splanchnic plexus
11, cephalic tap of the splanchnic plexus into the cephalo-mesial portion of the sinus venosus (common pulmonary vein)
12, communications between splanchnic plexus and precardinal vein
13, caudal tap of splanchnic plexus (hepatic portion of postcava)
14, communications between the splanchnic plexus and postcardinal vein

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[3] The engravings in this paper were supplied by the author.

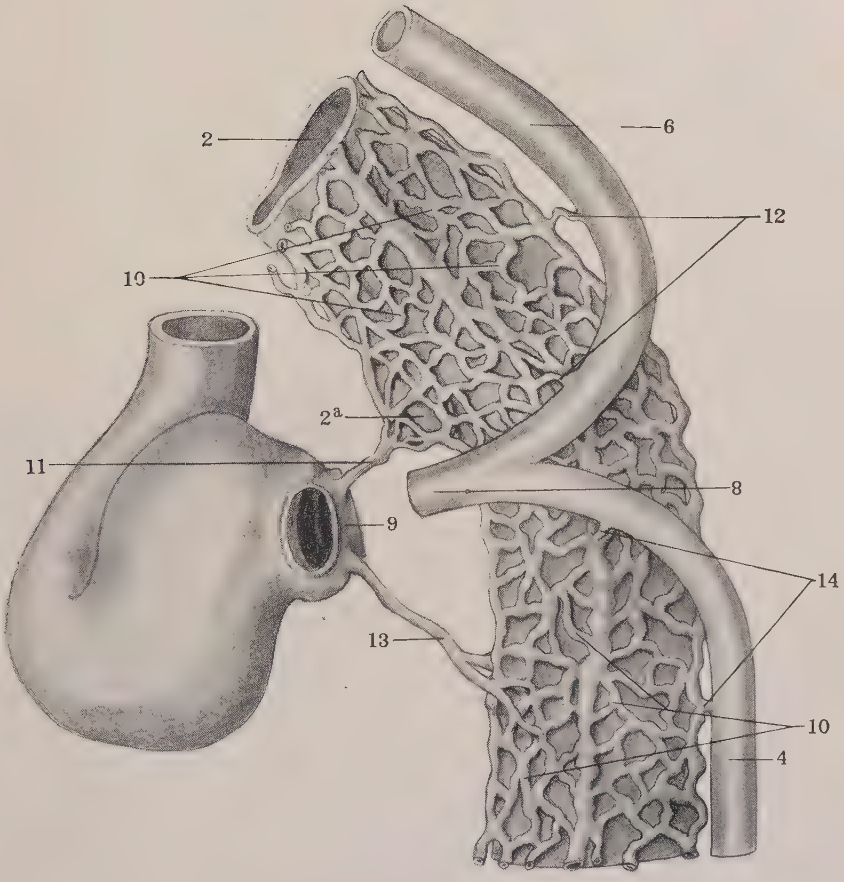
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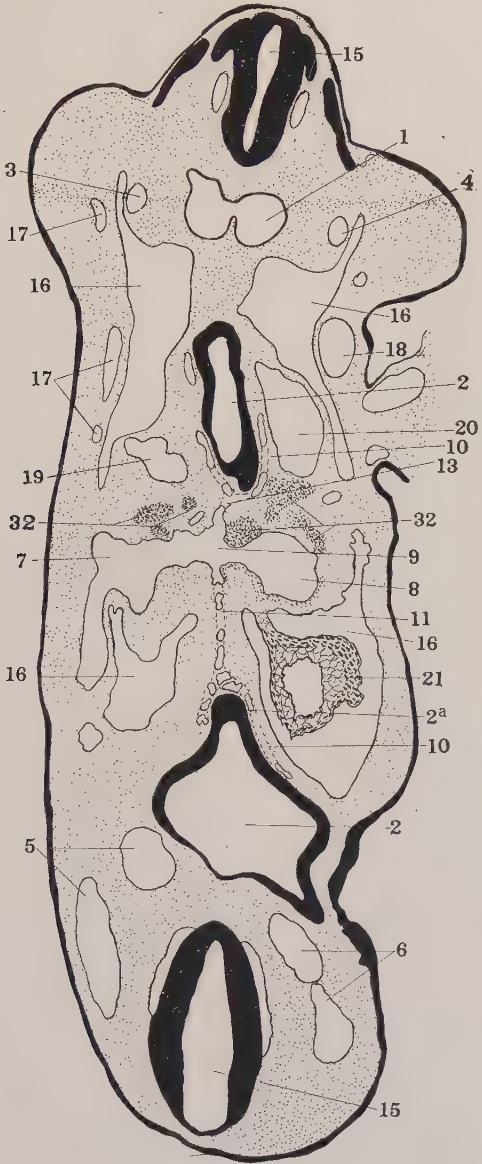
PLATE 2

Explanation of Figure

2 Composite drawing of superimposed cross sections of the 4.5 mm. embryo, Columbia collection no. 134, in the region of the cervical bend, × 150, reduced; schematic.

1, aorta
2, gut
2a, pulmonary anlage
3, right postcardinal vein
4, left postcardinal vein
5, right precardinal vein
6, left precardinal vein
7, right duct of Cuvier
8, left duct of Cuvier
9, sinus venosus
10, splanchnic plexus
11, cephalic tap of splanchnic plexus (common pulmonary vein)
13, caudal tap of splanchnic plexus (hepatic portion of postcava)
15, neural tube
16, coelom
17, right umbilical vein
18, left umbilical vein
19, right omphalo-mesenteric vein
20, left omphalo-mesenteric vein
32, liver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2a
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PLATE 3

EXPLANATION OF FIGURE

3 Right side of a wax reconstruction of the 5.18 mm. embryo, Columbia collection, no. 226, × 150, reduced.

1, aorta
2, gut
2a, pulmonary anlage
3, right postcardinal vein
5, right precardinal vein
9, sinus venosus
10, splanchnic plexus
11, pulmonary vein
12, caudal tap of splanchnic plexus (hepatic portion of postcava)
14, remnants of former communication between the thoracic and abdominal portions of the splanchnic plexus
21, conus arteriosus
22, common ventricle

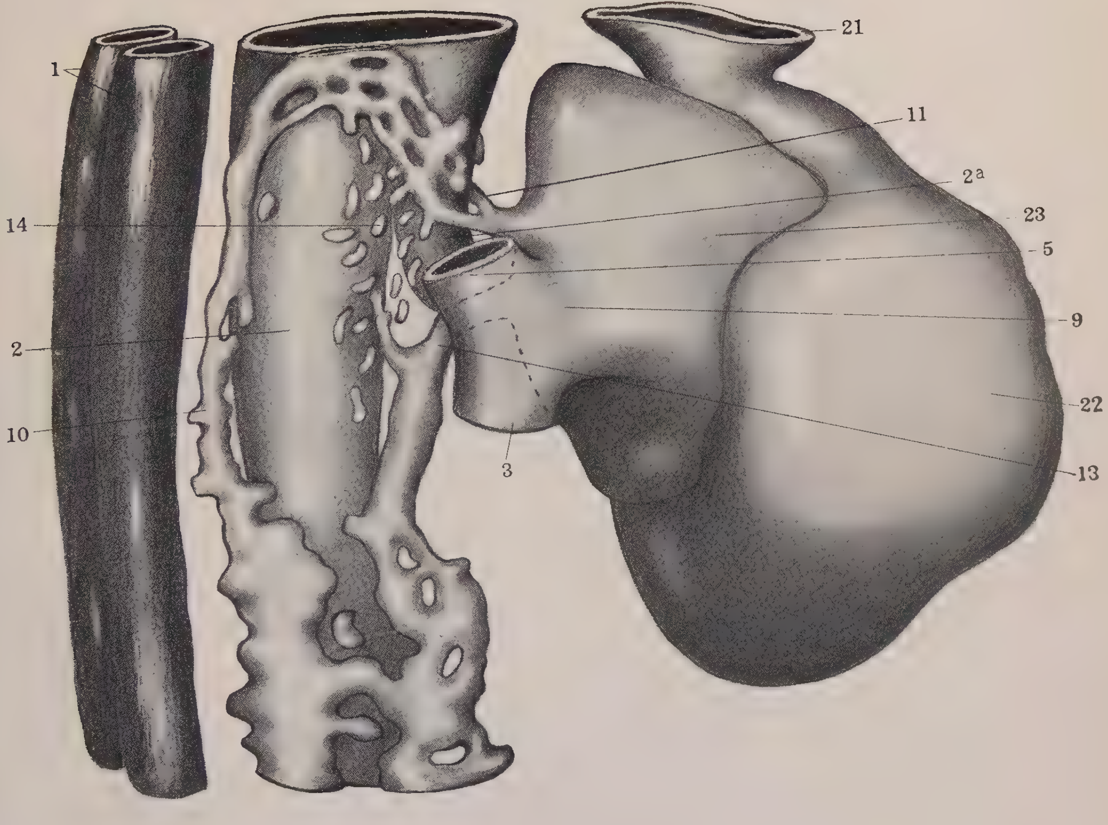
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PLATE 4

Explanation of Figure

4 Wax reconstruction of the 5.18 mm. embryo, Columbia collection, no. 226, × 150, reduced. Viewed from above, the top of the common auricle having been removed.

1, aorta
2, gut
2a, pulmonary anlage
4, left postcardinal vein
7, right duct of Cuvier
8, left duct of Cuvier
9, common opening of the cornua into the sinus
10, component parts of the splanchnic plexus
11, pulmonary vein
21, conus arteriosus
23, common auricle
38, auriculo-ventricular orifice

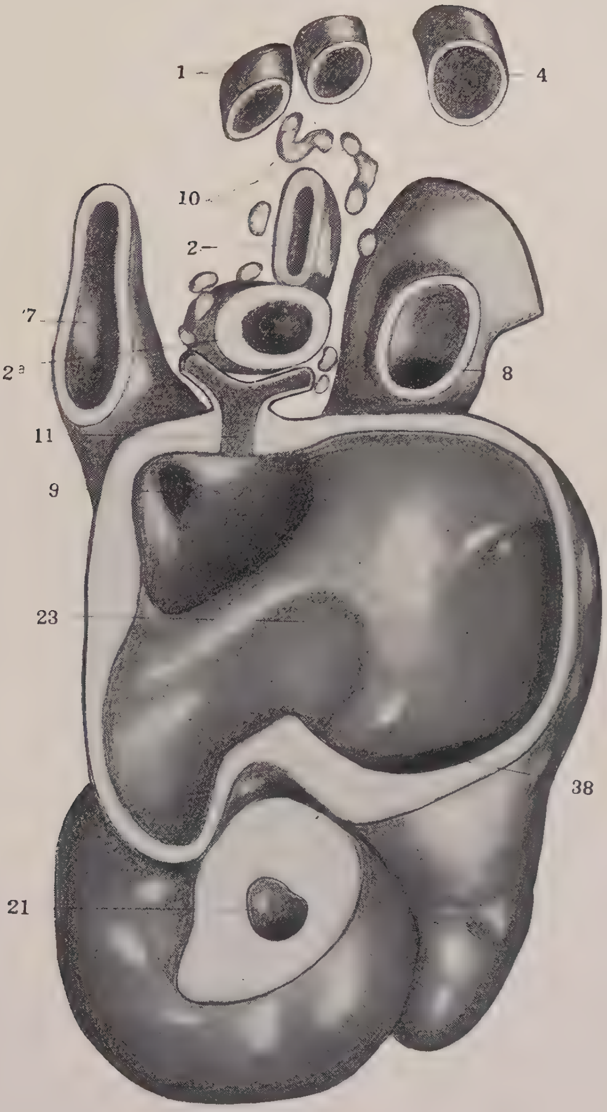
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PLATE 5

EXPLANATION OF FIGURE

5 Wax reconstruction of the heart of the 7 mm. embryo, Columbia collection, no. 266, × 75, reduced. Viewed from behind showing the crossing of the left duct of Cuvier to the right consequent to the shift of the sinus venosus.

2a, pulmonary anlage
3, right postcardinal vein
4, left postcardinal vein
5, right precardinal vein
6, left precardinal vein
7, right duct of Cuvier
8, left cornu of the sinus venosus
9, right cornu of the sinus venosus
11, pulmonary vein
13, caudal tap of the splanchnic plexus (hepatic portion of postcava)
22, common ventricle
26, right auricle
27, left auricle

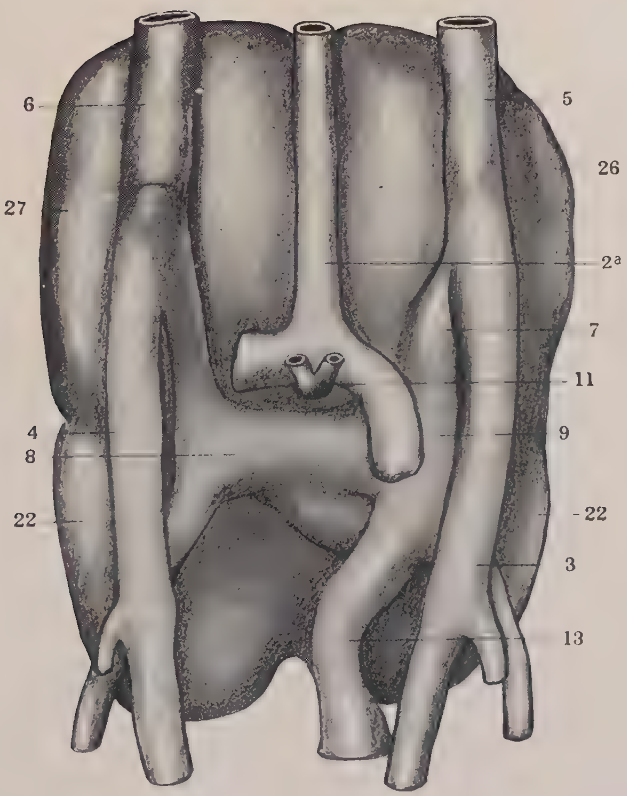
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PLATE 6

Explanation of Figure

6 Wax reconstruction of the 7 mm. embryo, Columbia collection, no. 266. × 75, reduced. Viewed from above, the top of the auricles having been removed.

1, aorta
2a, pulmonary anlage
8, left cornu of the sinus venosus
9, sinus venosus
11, pulmonary vein
21, conus arteriosus
22, common ventricle
26, primitive right auricle
27, primitive left auricle
38, auriculo-ventricular orifice
39, right valve of the sinus venosus
40, anlage of the interauricular septum

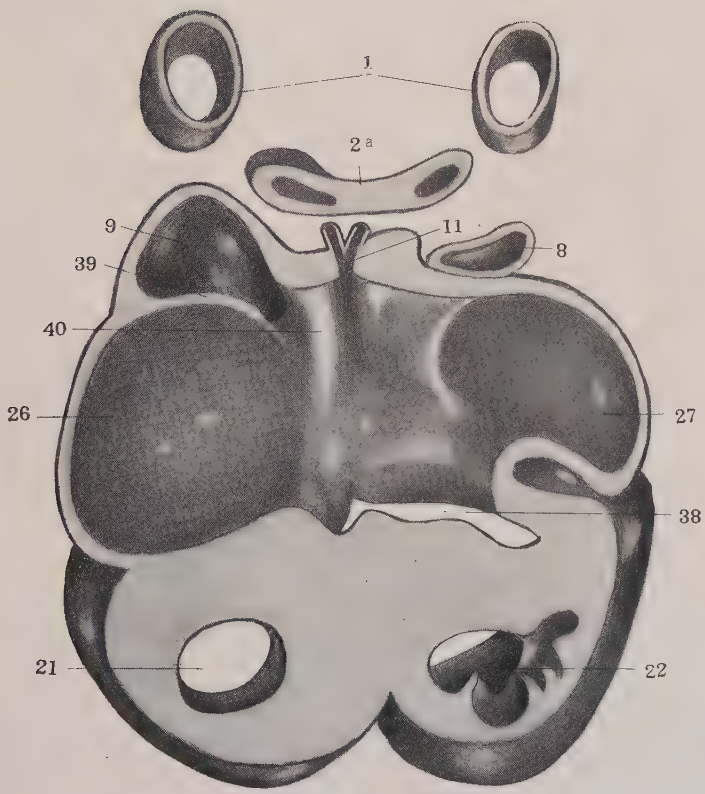
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PLATE 7

EXPLANATION OF FIGURE

7 Ventral view of congenitally abnormal heart.

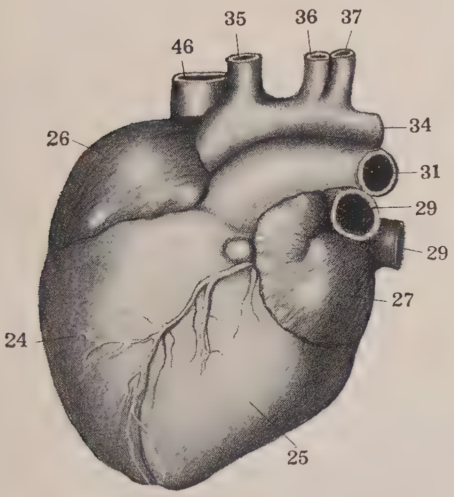
24, right ventricle
25, left ventricle
26, right auricle
27, left auricle
29, left pulmonary vein
31, left pulmonary artery
34, arch of the aorta
35, innominate artery
36, left common carotid artery
37, left subclavian artery
46, precava

8 Dorsal view of congenitally abnormal heart.

24, right ventricle
25, left ventricle
26, right auricle
27, left auricle
29, left pulmonary vein
30, right pulmonary artery
31, left pulmonary artery
33, azygos communis vein
34, arch of aorta
35, innominate artery
36, left common carotid artery
37, left subclavian artery
46, precava
47, postcava

9 Schema of abnormal pulmonary circulation, ventral view. The heart has been removed.

28, right pulmonary vein
29, left pulmonary vein
30, right pulmonary artery
31, left pulmonary artery
34, arch of aorta
41, right inferior phrenic artery
44, right lung
45, left lung
46, precava
47, postcava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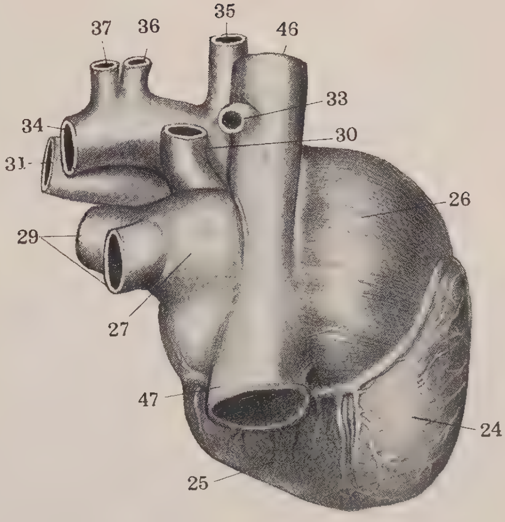
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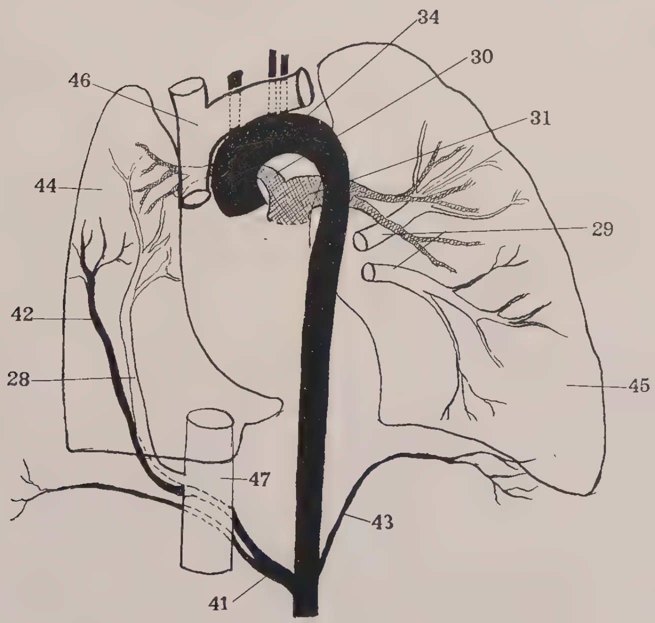
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Anatomists and zoologists, as well as other investigators who are adding so materially to the fundamental knowledge upon which scientific medicine is based, who depend upon the use of living animals for their researches, will be gratified to realize that one of the leading popular magazines has taken a firm stand in favor of scientific medical progress. From the August 16th issue of *Harper's Weekly*, now edited by Norman Hapgood, we clip the following:

ANTI-VIVISECTION

Some dozens of letters have come to us all at once, asking us to be fair in the vivisection controversy and to give "both sides." Some of these letters inform us that the writers will subscribe to this *Weekly* if we are fair, but not if we pursue a course hostile to the anti-vivisection crusade.

We have no intention of giving both sides. On the contrary, the support of the cause of scientific medical progress will be one of the things to which we shall be energetically devoted. We shall no more give both sides of the argument on experiment than we shall give both sides of the question of whether the household fly shall be encouraged in the dining-room, or sewers emptied into the city reservoir, or swamps kept for the breeding of mosquitoes, or smallpox patients permitted to ride on the street cars. We shall be extremely bigoted on the subject, and shall hope that the day will soon come when cancer will be added to the great diseases that have yielded to investigation.

OBSERVATIONS ON THE HISTOGENESIS OF PROTOPLASMIC PROCESSES AND OF COLLATERALS, TERMINATING IN END BULBS, OF THE NEURONES OF PERIPHERAL SENSORY GANGLIA

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FIFTY-FOUR FIGURES

In a study of the spinal ganglia of vertebrates, stained after the Ehrlich intravitam methylene blue method, Huber observed, especially in the spinal ganglia of amphibia, fine collateral branches arising from the intracapsular portion of the nerve process, having a recurrent course and ending beneath the capsule or on the cell body of the respective cell in relatively large discs or end bulbs. Similar structures, though not so successfully stained, were observed in the spinal ganglia of certain turtles and the rabbit. In the publication cited reference was had mainly to the presence of these structures as observed in the frog, incidental mention is made of their presence in the turtle spinal ganglia and no mention was made of their having been observed in mammalia, owing to the fact that that staining of these structures in the mammalian spinal ganglion was not wholly successful and the question of possible artefacts was given undue consideration. Little attention was paid to these structures until they were practically rediscovered by Cajal whose observations were made on the spinal ganglia of man and certain of the larger mammals stained after his silver impregnation method. Cajal designates these cells as "Regenerativer Typus oder Typus mit Fortsätzen, welche in verkapselten Kugeln endigen," and describes three main forms: (*a*) elements whose processes end in endocapsular bulbs. This is the most common variety and is found on cells of the glomerular type. The side processes are said to arise either from the

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cell body, from the axon cone or from one of the turns of the glomerulus. They have a diameter of from 0.3 μ to 0.4 μ enlarging as the end disc is approached and terminating in variously formed end discs, or bulbs; (*b*) Elements, with processes which pierce the capsule, and terminate in end discs situated in the interspaces of the ganglion. These are quite numerous in man and are quite variable. The processes are relatively fine and may arise from the cell body or from the endocapsular portion of the nerve process or again from its extracapsular portion and end at a variable distance from the cell. The end discs may terminate at some distance from the cell body, even in the nerve trunk outside of the ganglion; (*c*) Mixed forms, with transitions between endocapsular and extracapsular discs and elements having both types of discs. Dogiel in his excellent monograph on the structure of the spinal ganglia classifies neurones with processes terminating in end bulbs under Type II. This type is characterized as composed of cells from the main process of which arise side branches—collaterals—which terminate in platelets varying in form and size. He recognizes three subtypes: (*a*) cells from the main process of which there arise, usually near its origin from the cell, relatively short processes which may have a wavy or coiled course and end endocapsular in relatively large end discs; (*b*) cells from the main process of which there arise, at a variable distance from the cell, fine and relatively long collaterals which wind about in the capsule of the respective cell and terminate in variously formed plates; (*c*) cells from the extracapsular portion of the nerve process of which there arises usually a single fine collateral which may be relatively long, spirally wound about the nerve process and ends in the interstitial tissue in a relatively large end disc. Dogiel does not recognize fine processes arising from the cell body of the spinal ganglion cells and ending in end discs. Von Lenhossék has described and figured fine processes arising from the cell body and a turn of the glomerulus in spinal ganglion cells of the horse. Chase has also described processes terminating in end bulbs, the process being connected either with the cell body or with the axon Ranson's Type II, spinal ganglion cells are characterized as "Cells whose axons have collaterals ending in end bulbs." Three subgroups are considered: (*a*) cells having collaterals ending in end bulbs which arise before the axon leaves the capsule of the respective cell; (*b*) cells having collaterals which arise from the axon at some distance from its cell origin and pierce the capsule of some other cell, terminating in an end bulb which lies on the surface of this second cell; (*c*) collateral which run in the connective tissue of the ganglion and end in end bulbs surrounded by a special capsule. Ranson did not observe fine branches ending in end discs which arise from the cell body of the spinal ganglion cells, thus of the nature of dendritic branches. Levi has studied the spinal ganglia of fishes, reptiles and mammals by means of the silver impregnation method and has found the fine processes ending in end bulbs in the various forms examined. They are described as especially numerous in the cranial ganglia of primates, where the atypical forms of ganglion cells are said to constitute the prevalent type. He has considered also the histogenesis of these structures and this portion of his work will receive further consideration.

Fine processes arising from the cell bodies of spinal ganglion cells and as collaterals from their axons, and ending in relatively large end bulbs have received especial attention by neurologists and neuropathologists since it has been shown that they are present in much greater numbers in certain pathological conditions. Nageotte and later Marinesco and others have shown that they were quite numerous in the spinal ganglia of subjects afflicted with tabes, also numerous in transplanted spinal ganglia, or partly crushed ganglia or again ligated ganglia. Nageotte has regarded these structures as an exponent of a special type of regeneration to which he has given the name of 'collateralregeneration' in contradistinction to the regeneration observed at the end of a severed nerve. This hypothesis has been accepted by Marinesco and Bielschowsky. The latter has studied both the normal and pathological ganglia of man, using his well known silver method and gives numerous figures showing form and relation of these structures. He regards them as an evidence of an attempted regeneration and as found only on cell bodies and processes of neurones showing evidence of degeneration. His own words read as follows: "Die Regeneration ist niemals eine autochthone. An gesunden Neuronen zeigt sie sich nie. Sie erscheint stets als Folge einer primären Destruktion. Wo Sprossungsvorgänge an Zellen und Fasern stattfinden, können wir mit Hilfe unserer verschiedenen Methoden den Nachweis führen dass dieselben in ihrer Struktur mehr oder minder verändert sind." Cajal regards the hypothesis of Nageotte as giving the correct interpretation of the meaning of the cell process and collaterals ending in discs. His own words read as follows: "Wir sehen demnach gegenwärtig die kugeligen Verbreitungen als regenerierte oder neugebildete Nervenfasern und folglich als das Resultat eines transitorischen Bildungsvorganges an, der in allen Typen der sensiblen und sympatischen Zellen und selbst in den Nervenfasern der cerebrospinalen Centren vorkommen kann." Cajal does not regard the neurones showing these processes as necessarily pathologic. The regeneration is usually purposeless. Cajal compares these end discs to the end bulbs of regenerating nerve fibers. The 'Kugelphänomen,' to use his word, is regarded as an interesting process which has recently been well analyzed by Nageotte who should be credited with throwing light on an important biologic phenomenon. Rossi, who has extensively studied normal and pathologic spinal ganglia of man, groups the cells with processes ending in bulbs as follows: (*a*) Cells with processes the end bulbs or 'bolas' of which are endocapsular; (*b*) Cells with processes the end bulbs or 'bolas' of which are extracapsular and at times relatively far distant from the cell of origin; (*c*) mixed or transitional types. He discusses fully Nageotte's hypothesis of 'collateralregeneration' and reaches the conclusion that this is not substantiated. The large number of such structures found in pathological conditions, especially tabes, is not regarded as evidencing a regenerative process since the increase may be apparent rather than real, in that the pathological tissues may be much more receptive to silver impregnation than the normal tissues. He states, to use his own words, "Es wäre ja leicht möglich, und eine solche annahme ist weder unwahrscheinlich noch unlogisch, dass, wenn die Mehrzahl der Ganglienzellen sich im Zustande grosser Veränderung befinden, die fraglichen Fasern in Verhältnissen sein könnten, welche die Imprägnierungen mit dem Silbersalz begünstigen, und sie für die nachfolgende Einwirkung der Reduzenten mehr aussetzten." Rossi further lays stress on Levi's observations on the histogenesis of these structures and points out that the fact that these structures are present in relatively early stages of embryonic development would seem to indicate that they are normal structures and not expressions of regenerative phenomena. The hypothesis that the processes and collaterals of spinal ganglion cells, ending in end bulbs, are the products of regenerative activity of the neurones has led Ranson to see whether they are increased in number in ganglia after the division of the associated nerves. The left sciatic was cut in four dogs and after one month the associated ganglia were prepared by the pyridin-silver technic. The results of these experiments were entirely negative.

It is not at all difficult to find in the spinal ganglia of adult mammals, neurones presenting the various types of cell processes and collaterals ending in end bulbs, as described by authors, both for normal and pathological tissues. In a series of preparations of spinal ganglia of adult rabbits, cats and dogs, stained after the pyridin-silver technic of Ranson, modified by fixing the tissues by means of a preliminary injection of ammoniated alcohol, as described by Huber and Guild, such structures are readily found. It is not our purpose, however, to consider these structures as observed in adult ganglia, except to add that the neurones on which they are found do not present evidence of degenerative changes, and that the nonmedullated fibers of the ganglia are not thus accounted for, even to a minor degree, as might be supposed from the statements of Bielschowsky. Attention may be called to the fact that Ranson has clearly traced the nonmedullated fibers of the spinal ganglia to origin from small cells of these ganglia. It occurred to us that a study of the histogenesis of these structures might offer interesting data and our study was undertaken with this end in view. At the time when these observations were projected we were not aware of Levi's studies in this field. Our own observations, in part confirmatory, extend those of this observer and seem to us worthy of record, especially in view of the fact that an especial interest is attached to these structures by the neuropathologist. Our study is based in the main on material taken from rabbit embryos and young rabbits. Further on three-day-old rats and puppies about three weeks old. The study is confined largely to the lower cervical ganglia and the upper dorsal ganglia, mainly owing to the somewhat better staining obtained here than in the cranial ganglia, which material was used for other purposes, for which it was not permissible to cut the heads in smaller pieces. Where possible, by reason of size and convenience, the embryos and young animals used were subjected to a preliminary injection of the ammoniated alcohol before final fixation of the tissue. This is of advantage and adds to the method. The elements are better fixed and are slightly separated so that thicker sections may be studied to advantage. We also found it very convenient to combine decalcification with the silver technic. After the injection of ammoniated alcohol, or without this, the cervical and upper dorsal spinal column was removed with the surrounding muscular tissue, cut in segments having a length of about 1 cm., fixed in ammoniated alcohol, decalcified, subjected to silver impregnation and reduction, embedded in paraffin and cut serially. In the region selected the ganglia are relatively large and are arranged more nearly at right angles to the long axis of the cord than in other regions. In the sections the ganglia are oriented with reference to the cord and associated nerves, and are in no way affected by manipulation. The figures, as may be observed from the legends, are all taken from rabbit material, and mainly from the spinal ganglia of rabbits one day old, in which the series of developmental stages was most readily found. Similar stages are also found in the three-day-old rat material, so that it would be a simple matter to duplicate the figures here given from rat material. In spinal ganglia from six-day-old rabbits, cell processes and collaterals ending in bulbs are easily found, though what we have regarded as the early developmental stages are not numerous. In the spinal ganglia from 3-cm.-rabbit embryos, the cells are mostly of the type of bipolar cells, many showing early stages of single process formation. In the spinal ganglia of rabbits removed about one week before birth there are to be found series of stages showing spinal ganglion cell development, beginning with the late bipolar stage to cells with relatively well developed single processes with T- or Y-shaped division. Only here and there a few cells showing lobulation or early stages in the formation of the processes ending in end bulbs are seen. Certain of the most typical of these are figured. The spinal ganglia taken from puppies three weeks old show neurones with processes and collaterals ending in end bulbs, but these are not as numerous as in the rabbit material and show a somewhat later stage of development than the oldest stages figured by us. The material taken from the rabbits one day old, from which material most of our figures were made, had been well injected with ammoniated alcohol, prior to removal from the animals and final fixation in the ammoniated alcohol. The neurones in the ganglia seemed well preserved, both as to form and structure, many of the cells and processes showing neurofibrils. The structures figured, we believe, are not artefacts, due to possible shrinkage and consequent distortions of the cells.

The cell processes and collaterals terminating in end bulbs, may, according to their histogenesis, be grouped under three heads, though not very much weight is attached to such a classification, in that it is not always possible to project with certainty the future relations of these structures when seen only in anlage. The grouping is as follows.

1. It seems quite evident that a certain group of processes or collaterals arise as protoplasmic buds from the processes of the unipolar cells, the primary axons, and at a variable distance on this from the cells of origin. The majority of these collaterals appear to end ultimately on the cell body of some other neurone, certain ones perhaps in the interstitial tissue, though the possibility of certain ones having a recurrent course and ending on the cell of origin is not excluded.

2. Processes which arise as protoplasmic buds from some portion of the cell body. The point of origin may be near the axon cone or at a variable distance from it. In further development such buds do not become associated with the axon cone but remain as protoplasmic branches, perhaps of the value of dendrites. Later developmental stages indicate that certain of these branches

remain as endocapsular processes, while others pierce the capsule to end on some other cell or in the interstitial tissue.

3. Processes which arise from the cell body near or at the root of the axon cone which, as the axon cone and processes undergo further development become drawn on to the axon and thus become distinctly separated from the cell body. These processes or collaterals, it would appear, may end on the cell body of the cell of origin or perhaps also on the cell body of some other cell or in the interstitial tissue.

In the main, our figures are grouped with reference to such a classification. The figures are all drawn with the aid of a camera lucida, at a magnification of 1000, in the reproduction reduced to 500. It was found very helpful to use during the study of the preparations and while making the outline drawings with the aid of the camera lucida, a strong Welsbach light; many of the details being much more clearly visible than when daylight alone is used. In our selection of cells for drawings such cells as gave the full detail in one section were chosen. None of the figures represent graphic reconstructions. We believe that they portray the facts to be presented so clearly that we may be correspondingly brief with our morphologic description.

Figures 1 to 17 all show collateral branches developing from the nerve processes or primary axons and at variable distances from the cells which give them origin. All of the figures except 17 (6-day-old rabbit) are from spinal ganglia of rabbits one day old. Figures 1, 2 and 3 show the anlage of these collateral branches. In figure 1 is shown a short bud arising from the neuraxis a short distance from its origin. Such buds recognized here and there on fibers, stain a lighter brown than does the parent fiber and show a much looser arrangement of the neurofibrillar network than does the fiber. In figure 2 a similar bud, somewhat more distant from the point of origin of the process is seen as resting on the fiber; its relative size is thus clearly shown. In figure 3 is shown the anlage of a collateral given off from a primary axon just before its T-shaped division is reached. The length of this process could not be determined. Figures 4, 5 and 6 show early stages in the basal constriction of the bud like anlagen of collaterals and it may be seen that the bulbus ends stain usually a light brown, the stalks staining a somewhat darker brown. To bring out the perspective in the drawings, it was not always possible to retain the relative degree of coloration as presented in the preparations and therefore, certain of the buds and bulbus ends are figured as more deeply stained than is the case in the sections. Figures 7, 8, 9, 10 and 12 show progressive stages in the degree of constriction and elongation of the stalks of the respective collaterals ending in bulbs. In figure 7 may be seen a relatively large end bulb of somewhat irregular shape, resting on a cell other than that from which arises the process bearing the collateral branch. These collateral branches with the exception perhaps of that shown on the cell and process presented in figure 9, are extracapsular in origin. In this figure (9) the nerve process, as may be seen by altering the focus, is longer than the figure would lead one to suppose and is inserted at a deeper portion of the cell than is figured. Figure 14 shows a collateral branch with a large stalk and a bulbus end, also large, which appeared to rest on another cell. Figures 13, 15 and 11 show well formed collateral branches of about the thickness as found in adult ganglia, though as yet relatively short, ending in well formed end bulbs. The collateral branches enlarge slightly as the bulbs are reached, this section staining somewhat more deeply, this is as is described by Cajal. These three cells show clearly the variable distance from the cell body giving origin to the respective process, at which the collateral branches may arise. In figure 11 the end of the fiber as figured, is in the immediate vicinity of T- or Y-shaped branchings of other processes, the collateral branch appears therefore, to be given off near the branching of the respective fiber and may represent a later developmental stage of that shown in figure 3. In figure 16 there is shown a relatively large collateral branch, nearly as large as the parent fiber with extracapsular origin, sweeping over the parent cell and ending in a large disc surrounded by a distinct capsule, not figured. This shows a relatively late stage in development and is not unlike similar structures found in adult ganglia. This cell is situated immediately under the ganglionic capsule as is also the end disc. Figure 17, from the spinal ganglion of a six-day-old rabbit, shows clearly a collateral branch with relatively large end disc, arising from the process of one cell and ending on another cell, the latter cell showing the light halo which surrounds an end disc apparently resting on the cell body, and familiar to one of us from former work with the intravitam methylene blue method. A second fibril with cut end, arising from the collateral branch near its end bulb, is evident. This probably represents a second disc cut in sectioning. The collateral branch shows an enlargement at about its middle, which from structure and staining suggests the anlage of another end disc.

Figures 18 to 29 are given to show the development of processes ending in bulbus ends and arising directly from the cell bodies of ganglion cells. Such processes are denied by certain observers (Dogiel, Ranson) but are seen clearly as a distinct type in development. They develop as outgrowths from the cell protoplasm, lobulations of the same as stated by Levi and are not related in development to fenestration of cell protoplasm leading to festoon formation or protoplasmic loops or peripheral protoplasmic reticular formation as described for certain types of spinal ganglion cells, by a number of observers. Bielschowsky regards the protoplasmic branches of spinal ganglion cells as developed from protoplasmic loops, these breaking through at their highest point. He states, "Ich halte diese Gebilde für Henkelfragmente, die auf der Höhe des Bogens abgeschnürt worden sind." In our preparations there is at the stage of development here studied, and especially in the spinal ganglia, very little evidence of fenestration of the cell bodies of the ganglion cells. In figure 25 we present a spinal ganglion cell, including its process to and inclusive of the T-shaped division, in which there is shown a distinct outgrowth to one side of the cell body, slightly constricted at its base. This we regard as the anlage of a process ending in a bulbus end disc. The outline of the surrounding cells is so regular that the appearance presented by this cell is not regarded as due to distortion consequent to shrinkage. Our method of fixation by preliminary injection of ammoniated alcohol, we believe excludes this. Here and there cells presenting the same general appearance are to be observed. Figures 18 and 19 show slightly older stages of development, with constriction at the base of the outgrowth. Each cell shows only one outgrowth. This in itself precludes the fragmentation of a loop. The very large end bulb evident from the time of the anlage of the process argues against the assumption that these processes are developed by fragmentation of the protoplasmic loops. In figures 21, 22 and 23 are shown progressive stages in the constriction and elongation of the protoplasmic branches terminating in end bulbs. In figure 23 there is evidence of a second bud growing from the process figured and in figure 22 there is shown a process which after division ends in two bulbs, possibly a later stage of development of the condition shown in figure 23. Figures 24 and 26 show cells with their processes ending in large end bulbs, not unlike similar structures as observed in adult ganglia. Figure 24 presents further a cut collateral branch, arising from the process of the cell some distance from its origin, the end disc no doubt having been severed in sectioning the preparation. In figures 27, 28 and 29 are shown small protoplasmic processes ending in relatively small discs, varying in shape and having an endocapsular position and not unlike similar structures met with in adult ganglia. The figures presented appear to us to indicate a progressive development of protoplasmic branches ending in bulbus ends as observed in spinal ganglia. Certain of our figures are not unlike those presented by Marinesco and Minea (Neuro Biologica) showing the results of partial crushing of spinal ganglia. Their figures 4, 9, 10 and 11 appear to show what may be regarded as early stages of development of processes with end discs of spinal ganglion cells. Figures 24, 26 and 28 are from spinal ganglia of rabbits six days old, the other figures of this series are from the spinal ganglia of rabbits one day old.

The cells shown in figures 30 to 36 may be regarded as representing a subgroup of type 3 of our classification, in which the processes with end bulbs arise from the cell bodies of the ganglion at the base of the axon cones, which in further development are drawn on to the primary axons appearing to arise from them near their seat of origin. All of these figures except figure 31, which is from a spinal ganglion of an embryo rabbit one week before birth, are from spinal ganglia of rabbits one day old. Figures 31 and 32 represent cells which show early stages in the development of such processes, presenting each a relatively large lobule of protoplasm attached to the base of the axon cone by means of a short thick stalk. In figures 33 and 34 are shown cells in which the lobules of protoplasm, which are to form the end bulbs of the respective processes or collateral branches are attached to the primary axons slightly further from their place of origin than is the case in the preceding figures, as yet, however by short thick stalks. In the cells shown in these four figures (31 to 34) it seems quite clear to us that the bud developed either as an outgrowth from the cell body at the base of the axon cone or from the base of the axon cone itself and was drawn along the primary axon as it developed. In the cells shown in figures 36 and 37, the process for each cell, which may now be regarded as a collateral branch, is thinner and longer and ends in a relatively large end bulb. Here also it seems probable that these processes had their origin at the base of the axon cone and were separated from the cell body during later development. For the cells shown in figures 30 and 35 this mode of development can only be conjectured; we cannot exclude the possibility that in these cells the processes in question did not arise as collateral branches from the respective axons in about their present relative position. However, after a study of many similar examples it seems to us clear that there are to be found on the cells of the spinal ganglia, certain collateral branches which arise from the base of the axon cones, which in anlage are to be regarded as buds from the cell body of the respective cells and which are drawn on to the primary axons as these and the processes undergo further development.

In figures 38 to 45, is shown a group of cells which form a second sub group under division three of our classification. Of this series of figures all but figure 38, which is from the spinal ganglion of a rabbit embryo one week before birth, are from the spinal ganglia of rabbits one day old. In all of these cells the anlage of the process or collateral branch ending in a bulbus enlargement arose from the cell body of the respective cell at the base of the axon cone and retains this relation in further development. It is a question as to whether these processes are to be regarded as processes of the cell bodies of the ganglion cells or as collateral branches of their primary axons. Certain ones appear to remain endocapsular, others appear to pierce the capsule ending in discs which are extracapsular in position. Their relation to the glomerulus when this develops, could not be determined at this stage of development. In figure 38 is shown a cell taken from the spinal ganglion of a rabbit embryo removed about one week before birth, which shows the anlage of the processes of this type, as a bud from the region of the junction of the axon and cell body. Even at this early stage in development the bud like anlage shows a bulbus end with relatively short thick stalk. This figure resembles certain of the figures given by Levi (figures 11 to 13) taken from the spinal ganglia of 12-cm.-long Sus scrofa embryos. In figure 39 is presented a cell showing an early stage in the development of this type of process, with bulbus end and short thick stalk arising from the base of the axon cone. Figures 40 and 41 present cells showing older stages with longer and thinner stalks ending in conspicuous end bulbs. Figure 42 is inserted since it shows a cell presenting an end view of the axon cone and process of a stage similar to that shown in the two preceding figures and shows clearly the attachment of the process at the end of the axon cone. Figures 43, 44 and 45 present cells showing later developmental stages with relatively thin porcesses ending in conspicuous end bulbs much as are often seen in adult tissue. In figure 44 a second similar process, though less fully developed, may be seen and in figure 43 the enlargement found about the middle of the process figured seems to indicate the anlage of a second end bulb It is believed that this series of cells shows clearly the anlage and development of cell processes or collateral branches arising from cells near the bases of the axon cones and retaining this relative position in later developmental stages and probably in the adult cells.

In figures 46 to 54 we present a series of cells each showing more than one process, differing in mode of origin, or showing other special features. They are all taken from spinal ganglia of rabbits one day old. In figure 46 is shown a segment of a primary axon showing an early stage in the development of two collateral branches arising from a common stalk. The nerve cell of which this fiber is a part could not be determined in the section. The condition presented is unusual in that usually only a single collateral branch ending in an end bulb is observed in the course of the fiber some distance from its cell of origin. The collaterals and end bulbs in themselves show no special features. In figure 47 is shown a cell with protoplasmic processes arising directly from the cell body, as in type two, and a collateral branch arising from the primary axon, as in type one. Essentially the same appearances are presented by the cell shown in figure 48, with the exception that one of the processes arises from the base of the axon cone as in the second subgroup of Type 3. In figure 49 is shown a cell presenting a well developed protoplasmic process ending in a conspicuous bulb, to the left of the figure and a similar process in anlage to the right of the figure, further, a collateral branch arising from the primary axon at some distance from its origin from the cell body. These three processes on the same cell, present different stages of development. The cell shown in figure 50 presents an appearance not often met with. From the primary axon there arise three collateral branches, shown in early stages of development. The one most distally placed shows a lobulation indicating the formation of two end bulbs with collateral branches. One may conjecture that such a cell may develop into one "having two, three or more end bulbs which lie close together in a feltwork of fine fibers, the whole surrounded by a capsule" as described by Ranson. In figures 51, 52 and 53 are presented cells which show early stages in the development of two collateral branches from each of the respective primary axons, situated at different distances along the axon and showing progressive stages in development. They are in every respect like collateral branches shown in figures 1 to 17, except that here two collateral branches are seen in process of development on each primary axon, a condition now and then met with in adult spinal ganglia; although fully developed tissues are not so favorable for having both collaterals in the same plane so that they may appear in the same section. In figure 54 is shown a cell which presents an early stage in fenestration of the cell protoplasm at the base of the axon cone, at the same time showing a short collateral branch with end bulb.

Fenestration of the cell bodies of ganglion cells we have not often met with in the spinal ganglia of the stages studied. The cell presented may readily be interpreted as showing an early stage of development of a type of ganglion cell now well known from descriptions and perhaps more easily found, at least in the animals studied by us; rabbit, dog and cat, in the vagus ganglia. A cell type in which the axon arises by means of several branches which may further branch and anastomose and form complex loops from which collaterals with end discs may arise.

From a study of the material at our disposal we believe that we are warranted in concluding that the cell processes and collateral branches of spinal ganglion cells terminating in end bulbs are to be regarded as normal and necessary components of the peripheral sensory neurones. The fact that they show a regular course in development and metamorphosis and are developed at an early period in the functional activity of the peripheral sensory neurone seems to us to offer valid support for this view. In the rabbit, as has been seen, they make their appearance late in embryonic life and their production or development is especially active soon after birth. In our material from three-day-old rats, cell processes and collateral branches of spinal ganglion cells ending in end bulbs may readily be seen and the developmental stages as given for the rabbit ascertained. In the spinal ganglia of puppies about three weeks old, cell processes and collateral branches with end bulbs are found well developed and it is difficult to find the earlier developmental stages. Except for length of the collateral branches and cell processes ending in end bulbs, and a complexity in their course, those found in the spinal ganglia of newly born animals present essentially the same structure as those found in the spinal ganglia of adult animals, and would appear to be quite as numerous. In the newly born animals examined, the primary axons do not present the coil complex or glomerulus found in adult ganglia. The structure as a whole, as regards fenestration of protoplasm, division of primary axons in course or at axon cones, and so forth, is much simpler than in adult ganglia. It is difficult for us to conceive how such structures—cell processes and collateral branches ending in end bulbs—could be the exponents of regenerative activity, such activity affecting the peripheral sensory neurones late in embryonic life and soon after birth, the results of such regenerative activity—cell processes and collaterals with end bulbs—to remain inactive and nonfunctional and show no essential growth as age advances. It is at present difficult to ascribe a special function to such structures. We believe, however, that such function exists. It is not thought that they have simply a trophic function, subserving the nutrition of the neurone. It is quite possible that they may convey impulses. The fact that a cell process or collateral branch ending in an end bulb and arising from one cell may terminate on another cell, suggests this. They may serve to increase the surface of the cell giving larger, perhaps special fields of contact for the termination of other neurones. For the present, however, no definite statement as to the possible function of cell processes and collateral branches ending in end bulbs as found on the peripheral sensory neurones can be made. They deserve further study both from the experimental side and in pathologic conditions.

BIBLIOGRAPHY

Bielschowsky, M. 1908 Über den Bau der Spinalganglien unter normalen und pathologischen Verhältnissen. Jour. f. Psych. und Neurol., vol. 11.

Cajal, S. R. 1907a Die Struktur der sensiblen Ganglien des Menschen und der Tiere. Ergebnisse der Anatomie und Entwickelungsgeschichte. Bd. 16.

1907b Die histogenetische Beweise der Neuronentheorie von His und Forel. Ant. Anz. Bd. 30.

Chase, M. R. 1909 A histological study of sensory ganglia. Anat. Rec., vol. 3.

Dogiel, A. S. 1908 Bau der Spinalganglien des Menschen und der Säugetiere. Fischer, Jena.

Huber, G. Carl 1896 The spinal ganglia of Amphibia. Anat. Anz., Bd. 12.

Huber, G. Carl, and Guild, S. R. 1913 Observations on the peripheral distribution of the nervus terminalis in mammalia. Anat. Rec., vol. 7.

v. Lenhossék, M. 1907 Zur Kentniss der Spinalganglienzellen. Arch. f. Mik. Anat., Bd. 69.

Levi, G. 1907 Struttura et istogenesi dei ganglii cerebrospinali nei Mammiferi. Anat. Anz., Bd. 30.

Marinesco, G. 1908 Recherches expérimentales et anatomo-pathologiques sur les cellules des ganglions spinaux et sympathiques. Jour. f. Psych. und Neurol., Bd. 13.

Marinesco, G., and Minea, J. 1908 Recherches experimentales et anatomo-pathologiques sur les lésions consécutives à la compression et à l'écrasement des ganglions sensitifs. Neuro Biologica, vol. 1.

Nageotte, J. 1906 Régéneration collatérale de fibres nerveuses terminées par des massues de croissance, a l'état normal; lesions tabetique des racines medullaires. Nouvelle Iconographie de la Salpetrière, No. 3 (seen only in review).

Ranson, S. W. 1912 The strucure of the spinal ganglia and of the spinal nerves. Jour. Comp. Neur., vol. 22.

Rossi, G. 1908 Über einige morphologische Besonderheiten der Spinal ganglien bei den Säugetieren. Bemerkungen über die sogennannten Collateral-regeneration. Jour. f. Psych und Neurol., Bd. 11.

All of the figures are taken from spinal ganglia of rabbit embryos and very young rabbits, stained after the pyridin-silver method, combined with decalcification. The great majority of the figures are taken from tissue injected with ammoniated alcohol, prior to final fixation and hardening in the same. All of the figures were drawn with the aid of the camera lucida at a magnification of 1000 diameters, reduced in the reproduction to a magnification of 500 diameters.

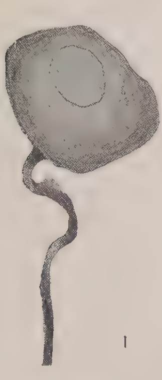
PLATE 1

EXPLANATION OF FIGURES 1 TO 17

This series of figures is given to show the anlage and histogenesis of collateral branches terminating in end bulbs and arising from the primary axons of spinal ganglion cells. Figures 1 to 16 are from spinal ganglia of rabbits one day old; figure 17, from the spinal ganglion of a six-day rabbit.

Figs. 1 to 6 Show the anlage as lateral buds and the basal constriction of such buds, of collateral branches with end bulbs arising from the primary axons of spinal ganglion cells.

Figs. 7 to 17 Show progressive stages in the metamorphosis of collateral branches ending in end bulbs which arise from the primary axons of spinal ganglion cells; also show the relative position on the primary axon of such collateral branches.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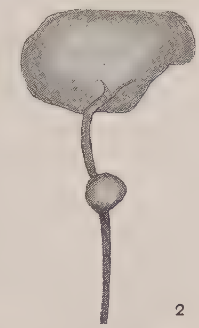
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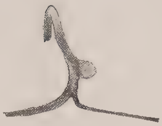
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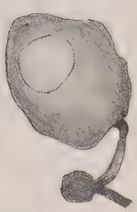
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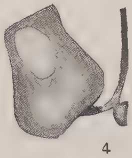
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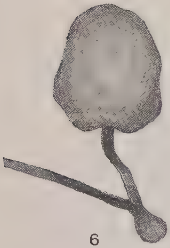
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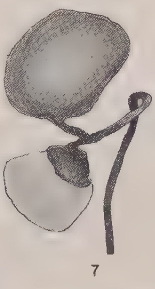
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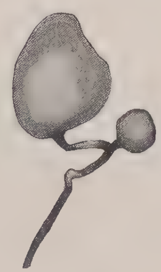
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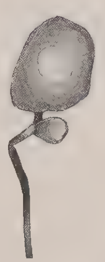
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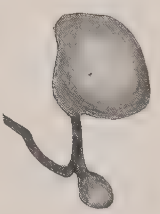
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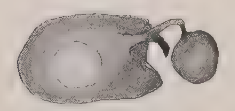
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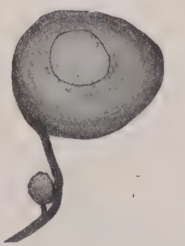
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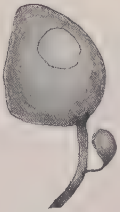
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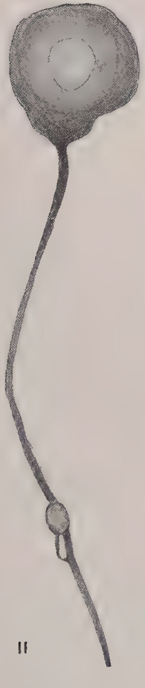
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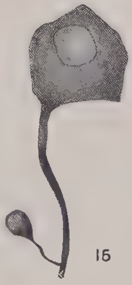
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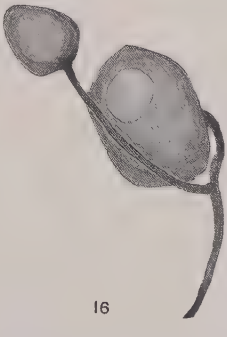
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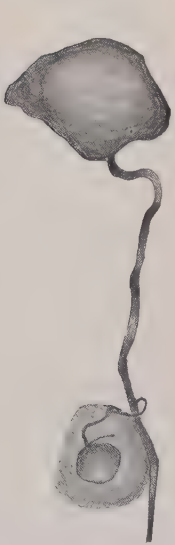
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PLATE 2

EXPLANATION OF FIGURES 18 TO 37

Figs. 18 to 29 Show the anlage and metamorphosis of protoplasmic branches ending in end bulbs, which arise from the cell body of spinal ganglion cells and retain such relation in the adult stage. Figures 24, 26 and 28 are from the spinal ganglia of rabbits six days old; the other figures of the series from spinal ganglia of rabbits one day old.

Figs. 18, 19 and 25 Show the anlage as protoplasmic buds, and the basal constrictions of such buds, of processes ending in end bulbs arising from the cell body of spinal ganglion cells.

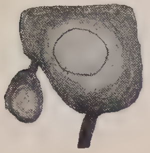
Figs. 20, 21, 22, 23, 24 and 26 Present progressive stages in the metamorphosis of protoplasmic processes ending in end bulbs and arising from the cell body of spinal ganglion cells.

Figs. 27, 28 and 29 Present cells with short protoplasmic processes ending in relatively small variously shaped end discs with endo-capsular position.

Figs. 30 to 36 Present cells showing the anlage and metamorphosis of protoplasmic or collateral branches ending in end bulbs, which arise from the cell body at the base of the axon cone, which as the processes and axons undergo further development are drawn on to the axons, thus loosing their connection with the cell body.

Fig. 31 Taken from the spinal ganglion of a rabbit embryo one week before birth presents the anlage of such a process as the protoplasmic bud with basal constriction arising from the cell at the base of the axon-cone.

Figs. 30, 32 to 37 Show progressive developmental and metamorphic changes of such processes and show a wandering of their anlagen from the base of the axon-cone to a position on the axon.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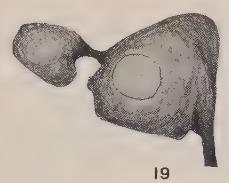
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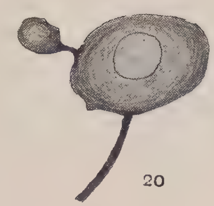
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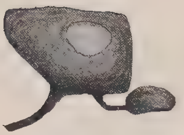
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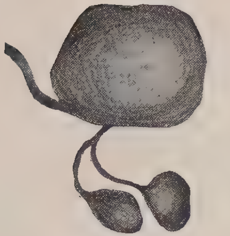
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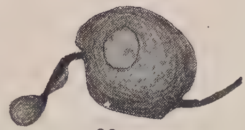
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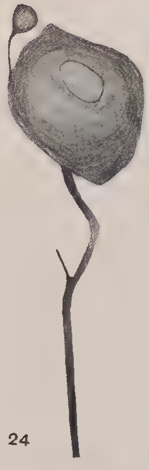
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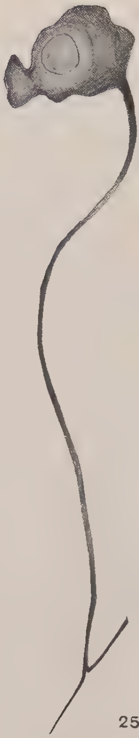
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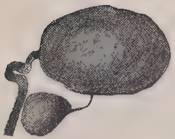
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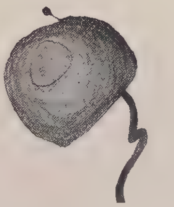
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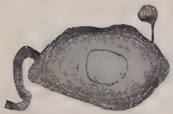
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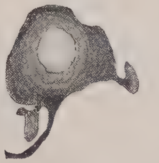
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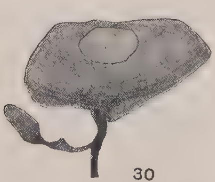
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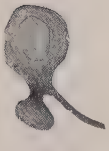
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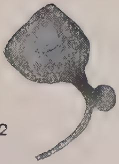
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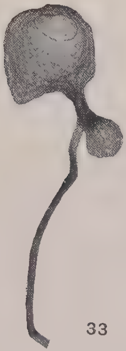
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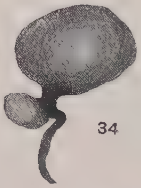
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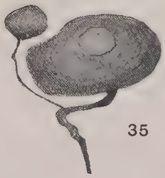
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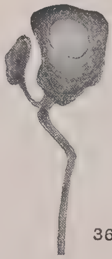
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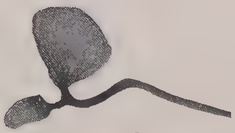
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PLATE 3

EXPLANATION OF FIGURES 38 TO 54

Figs. 38 to 45 Present a series of cells showing the anlage and progressive metamorphosis of protoplasmic branches ending in end bulbs which arise from the base of the axon-cone and retain this relative position in later stages of development.

Fig. 38 From the spinal ganglion of a rabbit embryo one week before birth and shows the anlage as a bud of protoplasm with basal constrictions arising from the cell at the base of the axon-cone.

Figs. 39 to 45 From the spinal ganglia of rabbits one day old, show progressive stages in the metamorphosis of protoplasmic buds arising from the base of the axon-cone and developing into processes with end bulbs which retain this relative position.

Fig. 46 Spinal ganglion cell of a one-day rabbit. Primary axon with branched collateral, each branch ending in an end bulb.

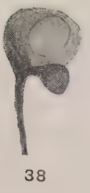
Fig. 47 Spinal ganglion cell of a one day rabbit. Protoplasmic branch which arises from the cell body and collateral branch arising from the primary axon, each ending in an end bulb.

Fig. 48 Spinal ganglion cell, one day rabbit. Well developed protoplasmic branch ending in conspicuous end bulb, similar branch in anlage and collateral branch which arises from primary axon.

Fig. 50 Spinal ganglion cell, rabbit one day old. Primary axon from which arise three collateral branches with end bulbs one of which is lobulated.

Figs. 51, 52, 53 Spinal ganglion cells, one-day rabbit. Present each a primary axon from which arise two collateral branches ending in an end bulb; progressive stages in the metamorphosis of such.

Fig. 54 Spinal ganglion cell, one-day rabbit. This shows fenestration of protoplasm at the base of the axon cone.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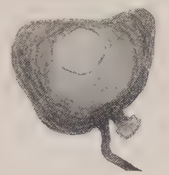
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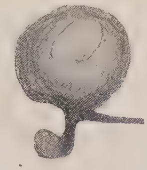
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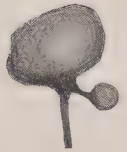
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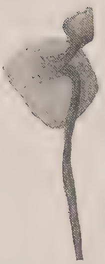
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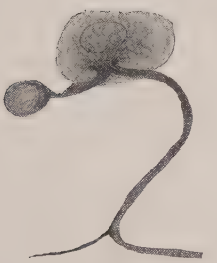
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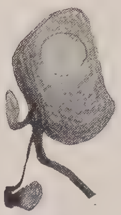
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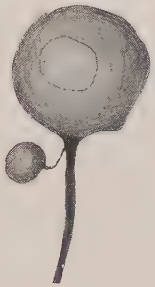
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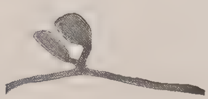
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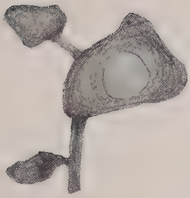
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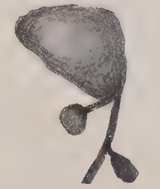
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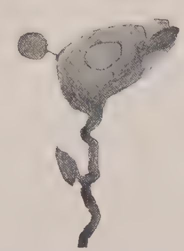
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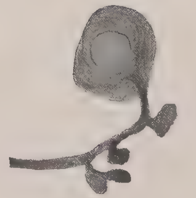
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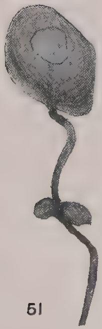
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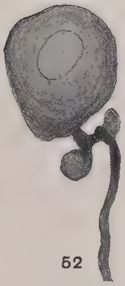
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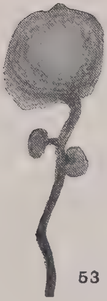
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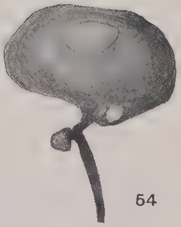
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OBSERVATIONS ON THE TEMPORO-MANDIBULAR ARTICULATION

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FIVE FIGURES

In studying the literature on the temporo-mandibular articulation there are certain matters that are indefinite and unsatisfactory. Out of four commonly used text-books of anatomy, two mention the platysma myoides muscle as one that opens the mouth; all give the digastric; one, only, speaks of the external pterygoid as assisting in this process; two give the mylo-hyoid; three, the genio-hyoid; while one adds the genio-hyo-glossus and infra-hyoid group. Protrusion of the jaw, according to all, is affected by the external pterygoid—assisted by the temporal, adds one—and two mention the internal pterygoid. All agree that the temporal muscle retracts the jaw, and one adds the masseter.

A student of the mandible would be puzzled by the data in regard to the action of the different muscles affecting it, or said to do so.

The existence of a deep glenoid fossa and of a prominent articular eminence is not satisfactorily explained, nor is the presence of the interarticular fibro-cartilage, or meniscus, well accounted for. Why does a part of the first visceral arch persist as the spheno-mandibular ligament? and why do we find a powerful thickening of a part of the fascia about the parotid gland, known as the stylo-mandibular ligament? Is there any function for either of these so-called ligaments?

Dr. Henry James Prentiss, professor of anatomy at the State University of Iowa, under whose stimulating leadership I have had the good fortune to work, suggested that I investigate especially this region of the jaw joint, in reference more particularly to the stylo-mandibular ligament and its value, and to verify and establish, if possible, certain tentative conclusions he entertained concerning the problem of depression of the jaw.

This paper attempts to show the results of my work on this matter.

To anyone observing the motions of the jaw in the living, it is apparent that the mouth opens ordinarily by a positive, direct action, not passively, as by its own weight.

To be opened by any of the supra-hyoid muscles, it would be essential that the hyoid bone be first fixed, or even lowered, by the infra-hyoid group of muscles; but that this does not happen, except during *forcible* depression of the jaw, it is easy to demonstrate. As the platysma myoides is attached at its lower part to the skin of the chest, a fact noted in most text-books, and seen in most of my dissections (although one well-known work speaks of its attachment to the deep fascia of the chest) it is hard to see how the lower attachment can be fixed to allow this muscle to depress the jaw. It is also easy to show in the living that the platysma does not open the mouth.

In the study of muscular action it is unusual to find a muscle inserted in the long arm of a lever, farther from the fulcrum than the place where the work is done, that is, that the 'power arm' should be longer than the 'weight arm.' Yet such is the case for practically every one of the muscles given as depressors of the mandible. In this way the speed, desirable for such an action is sacrificed to the power, not needed for the simple opening of the mouth. I might add that the length of the fibers of most of the supra-hyoid group does not allow of contraction sufficiently extensive to produce half the amount of motion seen in opening the mouth. For these reasons and for others that I shall advance, it is my belief that the muscles listed in the various text-books as depressors of the jaw are not ordinarily used for this purpose, and though they may assist under special conditions, are never solely responsible for such action.

From dissections made by others and myself at the State University of Iowa during the past few years, and from fresh dissections made there last summer, I made a careful study of this region and constructed a working model of the skull and mandible, following out as accurately as possible, every detail of muscular and ligamentous attachment, and making an artificial temporo-mandibular articulation with its capsule and meniscus. This model was then put into what might be termed 'physiological' working order, so that the muscles might be correlated when desired. The results obtained from manipulation of this model were carefully observed. In my belief this method of study of this rather intricate joint has cleared up some of the obscure points that I mentioned at the beginning of this paper.

To explain these results let me describe the construction of the model.

A specimen of human skull and jaw with perfect dentition was secured. By fitting the two together in normal articulation of the teeth, as the dentists put it, a definite interval between condyle and glenoid fossa was developed, the exact interval occupied by the meniscus, which normally separates the two surfaces. An artificial meniscus of velum rubber, such as is used by dentists in cases of cleft palate, was then made for me by Dr. C. W. Wilkinson of the Dental College. This was modeled to fit this special joint, copying the type seen in dissected and sectioned specimens. It was fastened in place exactly as in life, and an external lateral ligament was constructed and properly attached. To its anterior end was fastened the artificial upper head of the external pterygoid muscle, which in reality is inserted practically entirely in the meniscus.

A stylo-hyoid ligament of wire was made. Running downward and forward from this to the hind border of the mandible, near the region of the inferior dental foramen, was placed a catgut stylo-mandibular ligament, the tension of which could be easily adjusted.

The upper head of the external pterygoid muscle was formed by attaching a cord to the anterior edge of the meniscus and carrying this in the direction of the muscle fibers through a hole in the skull and then over pulleys until it was readily accessible to the operator in front of the specimen. In the same way cords, representing in their direction the exact courses of the muscles, were run for the lower head of the external pterygoid from its insertion in the neck of the condyle; for the internal pterygoid from the mesial surface of the angle, and for the digastric from its insertion near the symphysis. These were also brought to a common locality in front of the model, where they could be easily distinguished and manipulated. The digastric was considered to represent sufficiently well the fibers of the mylo-hyoid. The temporal muscle was constructed in a similar way by using rubber bands, whose tension could be varied at their attached ends of origin. Two such bands were attached, one running in the direction of the anterior, and the other, of the posterior fibers. The anterior fibers were considered to represent those of the masseter also. Thus, by making taut the bands, these two muscles were always in a state of tonic contraction.

By a simple arrangement of the strings it was so managed that the two heads of the external pterygoid, the internal pterygoid, and digastric, could be worked in pairs, or separately for each side, while the tension, the tonus in the living subject, of the entire system was maintained by the rubber bands introduced in the course of a few of these muscles. By manipulating the strings representing certain of these muscles it was possible to produce the different actions of opening and closing the mouth, of protrusion and retraction, and of trituration, exactly as they are seen in the living (fig. 1).

In opening the mouth, at the very first indication of separation of the teeth, the condyle was seen to advance, and the angle to retract. The ramus, half-way between these parts, near the location of the inferior dental foramen, although descending a short distance at first, presented almost a fixed point about which, as on a transverse axis, the jaw rotated. In closing, the reverse was seen.

In chewing, the condyle of one side advanced, that of the other retreated slightly, while the mouth opened a little, to an amount equal to the length of the cusps of the teeth. The lower buccal cusps were moved laterally until they came directly beneath the line of the upper buccal cusps. The process was then reversed; the lower buccal cusps, being continually applied with some force to the upper teeth, slid back to their normal position in the sulcus between the lingual and buccal cusps of the teeth above, the mouth closed, the advanced condyle retreated, and the retreated condyle advanced, to their normal positions. This movement could be effected equally well on either side.

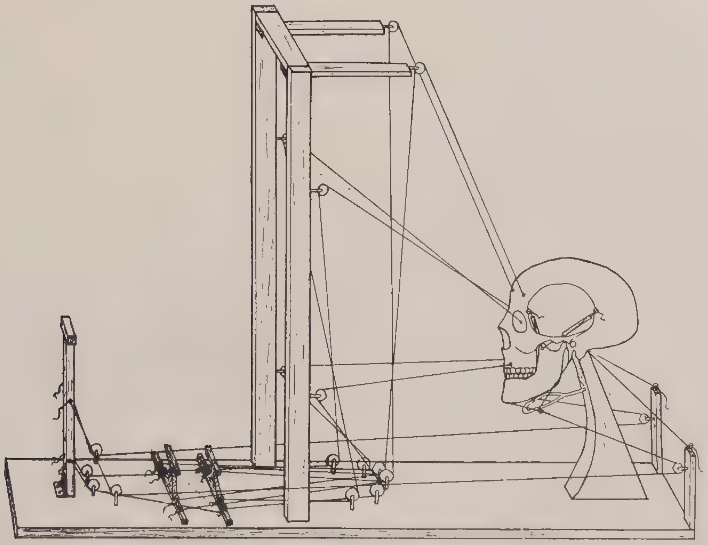


Fig. 1 Semi-diagrammatic drawing of model. The pair of strings passing through forehead act as internal pterygoid muscles; those passing through orbits, as upper heads of external pterygoids; those passing horizontally outward from just above the upper teeth, as lower heads of external pterygoids; the lowest pair as digastrics. Pulling back and releasing the upright at the left end of the drawing opens and closes the mouth; rotating, back and forth through a small arc, the smaller pieces which are pivoted on a central point, produces trituration, one for the right, the other for the left, side of the mouth.

The manner by which the mouth was opened was as follows. Both heads of the external pterygoids were contracted—that is, the cords representing these muscles were pulled—against the constant tonus, or tension, of the temporal, masseter, and internal pterygoid muscles of both sides. This of course advanced the two points of insertion of the two heads of the external pterygoid —the meniscus and condyle. At the same time it quickly made taut the stylo-mandibular ligament, making firm its point of attachment just behind the inferior dental foramen, and fixing that part of the ramus, except in so far as the elasticity and obliquity of this ligament allowed this point to descend a short distance—the amount of the descent of the condyle from the glenoid fossa to the articular eminence.

This fixation of the mandible in the region of the attachment of the stylo-mandibular ligament caused the symphysis to descend, and the angle to recede as the condyle advanced. The condyle was thus made to rotate also on its transverse axis against the surface of the meniscus above it, which was simultaneously advancing on the eminence, the two parts constituting a sort of traveling hinge-joint.

The mandible was depressed proportionally as the condyle advanced, in the exact ratio between the long and short arms of the lever, whose fulcrum was situated at the attachment of the stylo-mandibular ligament, and whose ends were the symphysis and the condyle (fig. 2).

If the contraction of the digastric was added to that of the external pterygoid it hardly altered the motion. It seemed to prevent too great tension on the stylo-mandibular ligament, when too strong a pull was made on the external pterygoid cords, and to keep the condyles from advancing too far on the articular eminences. Its function seemed to be that of a muscle to assist in *forcible* opening of the mouth, but probably not needed ordinarily in such action.

The chewing was effected in the following manner: If the chewing was to be done, for example, on the left side of the mouth, the two heads of the right external pterygoid muscle were 'contracted,' causing the right condyle to advance and the left to retreat, while the jaw dropped slightly. This motion was continued until the lower teeth swung half their diameter to the left, the cusps of the lower teeth following the transverse grooves between those of the upper. Then by contracting the temporal, masseter, and internal pterygoid muscles of both sides, especially the left internal pterygoid, the reverse motion was accomplished with as much pressure as desired on the grinding surfaces of the teeth. No pull on the left external pterygoid, to return the receded left condyle to its normal position, seemed necessary, for it tended to open the mouth. The pull of the left internal pterygoid muscle, due to the direction of its fibers, returned the receded condyle very effectively, and at the same time closed the mouth firmly together and swung the teeth mesially to their original position. To chew on the other side the action was just the opposite, and the two motions could be easily alternated.

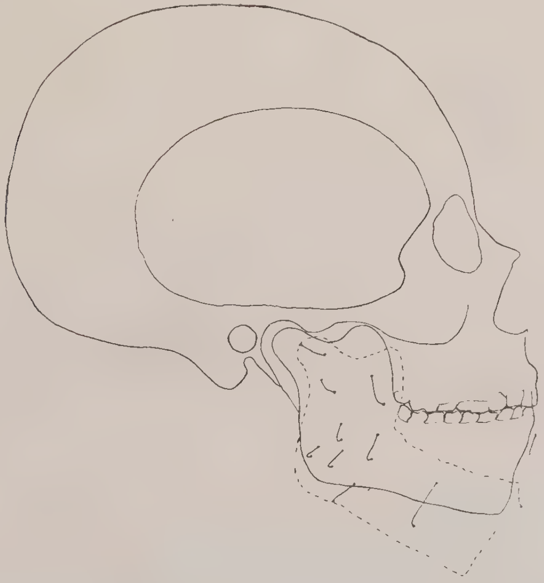


Fig. 2 Camera drawing from photograph taken of model while mouth was being opened. Dotted line gives position of the mandible when wide open. Curved lines running between dots show actual path traversed by illuminated points fastened to the mandible. The axis of rotation is thus shown to be near the attachment of the stylo-mandibular ligament.

In an article in the Boston Medical and Surgical Journal in 1889 Charles E. Luce gives the results of his attempts to photograph the motion of bright points located on different parts of the jaw during the motions of opening and closing. The paths followed by these points as photographed, correspond almost exactly with those of points similarly placed on the model.

A. Gysi, of Zurich, gives in the Dental Cosmos in 1910 diagrams of the paths traced by the cusps of the different teeth in the action of trituration. Their motion was exactly like that of the cusps of the teeth of this model when the process of chewing was effected.

Any further proof of the fact that the mouth is ordinarily opened by the action of the external pterygoids of both sides working simultaneously, just as trituration is effected by the external pterygoid of one side only, is furnished by an examination of this model.

In the course of my work on the motions of the mandible, certain facts, other than those stated above, were noticed and may prove of interest.

An examination of a series of sagittal sections of the meniscus and adjacent parts of the cadaver, or of the interval between condyle and glenoid fossa when the teeth of a good specimen of skull and mandible are held in proper apposition, reveals a very characteristic shape of the meniscus.

At the highest point of the condyle, or at the bottom of the glenoid fossa, it is thickest; where the anterior wall of the fossa joins the posterior part of the articular eminence it is thinnest; in front of this it grows thicker again to the anterior edge into which is inserted the upper head of the external pterygoid; behind the thickest part it quickly thins out and becomes fibrous, this fibrous portion continuing backward until it fuses with the posterior part of the capsule to become attached to the back part of the neck of the condyle (fig. 3).

In this way when the anterior end is pulled forward by the upper head of the external pterygoid the whole meniscus can advance with the condyle. In fact this upper head is indirectly pulling on the condyle, through the attachment of the meniscus posteriorly, just as the lower head pulls on it directly.

The direction of pull of this upper head is such as to apply the cartilage more closely to the eminence above, making it at the same time very taut. As the meniscus is moving, not along a straight path, but along the very curved eminence, it does not advance anteriorly in a linear direction as far as the condyle is advanced by the straight pull of the lower head of this muscle; the direction of whose fibers is downward as well as forward. Further, the lower head, being longer than the upper, for the same degree of contraction, moves the condyle a greater distance than the upper head moves the meniscus.

If then the condyle is traveling farther ahead than the meniscus, its upper rounded surface must slide forward on the under surface of the meniscus. This was well shown both on the dissected cadaver and on my model.

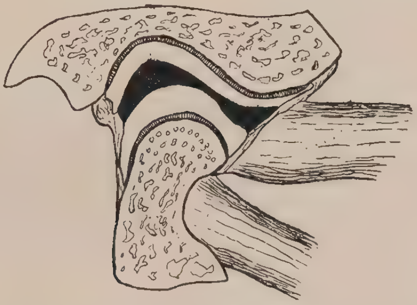


Fig. 3 Sagittal section of temporo-mandibular articulation. Meniscus in solid black; anterior and posterior walls of capsule are on the stretch, as the condyle is artificially separated from the fossa above. The upper head of the external pterygoid muscle is shown attached to the anterior end of the meniscus, while the lower head is inserted directly into the neck of the condyle.

It was found that when the condyle was advanced to a position beneath the lowest part of the eminence, there intervened between the bones the thinnest part of the meniscus. In this position of the jaw—when the mouth is widely opened—the space between the back part of the advanced meniscus and the otherwise empty glenoid fossa was filled by a well marked pad of fat connected with the lax posterior part of the capsule, much as a similar pad in the elbow joint fills the olecranon fossa during flexion of the forearm (fig. 4).

Thus the condyle has descended from its original position beneath the thickest part of the meniscus to its new position beneath the thinnest part—an actual descent much less than would appear to be the case on the articulated skull, or in a cadaver, when the condyle, but not the meniscus, is made to advance in attempting to follow the action of the mouth as it takes place in the living. If one considers the plane along which the fibers of the lower heads of the external pterygoids act, it is seen to be very nearly the same as that of a plane drawn tangent to the upper surfaces of the two condyles in the closed and opened positions of the mouth. Thus because of the manner in which the relations of the condyle to the bony parts above it are altered by the intervening meniscus, the articular eminence offers very little resistance to the forward and downward pull of the lower head of the external pterygoid, and the mouth opens with ease by the pull of the two external pterygoids alone. In opening the mouth, of course, the condyle also rotates beneath the meniscus, making this, as I stated earlier, a sort of moving hinge-joint. The apparent depth of the glenoid fossa then offers no

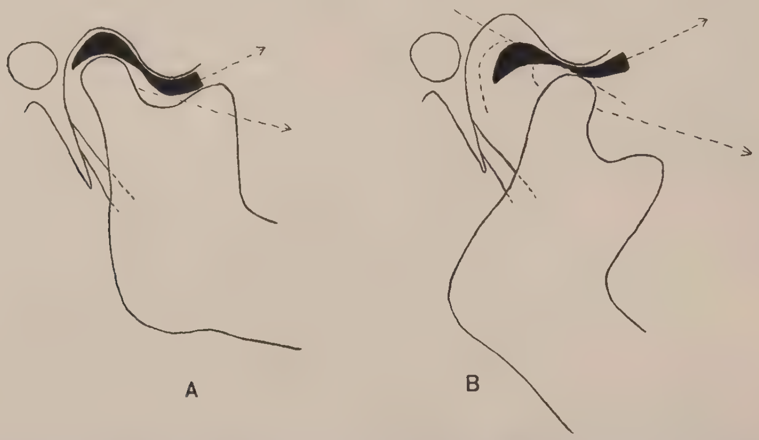


Fig. 4 Diagram to show relations of condyle, meniscus, and glenoid fossa when mouth is shut and open. In either drawing the arrows indicate the direction of pull of the upper and lower heads of the external pterygoid muscle. The stylomandibular ligament is shown running down from the styloid process. In the right hand drawing the position of the condyle when the mouth is closed is shown by dotted lines. The dotted line tangent to the condyle, in its two positions, shows approximately the plane of advance of the condyle when the mouth opens.

real hindrance to the motions of the jaw, and yet allows the existence of a tough but yielding structure between the bones, to take, in any position of the jaw, the strain of a sudden pull of the closing muscles, as when any object, large or small, is bitten—for instance, in the cracking of a walnut, or the crushing of a cherry stone, between the teeth.

It is easily demonstrable that certain fibers of the masseter and the posterior fibers of the temporal muscles are inserted in the anterior part of the capsule near the front border of the meniscus. When these muscles, as a whole, help to close the mouth, these special fibers tend to return the meniscus to its proper position, a condition also favored by the posterior attachment of the meniscus to the condylar neck itself.

In closing the mouth it is evident that the posterior fibers of the temporal, through their insertion in the ramus, pull the condyle back to its original position, and thus become the direct antagonist of the external pterygoid muscle. There is, however, in this reversed motion no possibility for the stylo-mandibular ligament to fix the region of its insertion, making it a point of rotation, for a pull on any of the closing muscles tends to relax this ligament. But, as the posterior fibers of the temporal are pulling backward and upward the upper part of the ramus, the masseter and internal pterygoid are pulling forward and upward the lower part, thus rotating the jaw as a whole about a transverse axis drawn between the two areas of insertion. This makes the point of rotation on each ramus near the inferior dental foramen, exactly where we have found it in the action of opening the mouth.

In fact, in *forcible* opening of the mouth, the condition of the external pterygoid pulling forward above, and the digastric pulling backward below, corresponds very closely to the condition obtained in closing the mouth, just stated, where the posterior fibers of the temporal pull backward above and the masseter and internal pterygoid pull forward below (fig. 5).

As a matter of conjecture, does it not seem probable that the spheno-mandibular ligament, inserted as it is in the lingula and region of the inferior dental foramen, persists in order to assist the stylo-mandibular ligament in its function of helping maintain a transverse axis of rotation for the mandible when the mouth is opened? At least it suggests a reason, when otherwise none is given, for the persistence of that portion of the first visceral arch.

This model, to recapitulate, demonstrates the following:

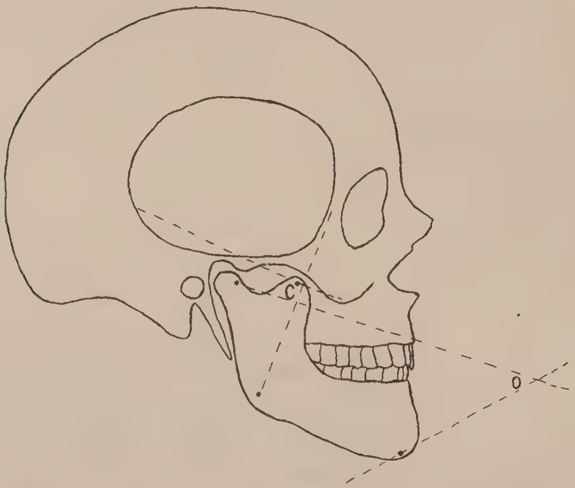


Fig. 5 Diagram to show relation between lines of force of the muscles, which forcibly open, and which close, the mouth. The two lines meeting at O represent the direction of pull of the external pterygoid and digastric muscles, used in *forcible* opening; those meeting at C represent the direction of pull of the masseter (the fibers of the internal pterygoid, so far as closing the mouth is concerned, are practically parallel with those of the masseter) and the posterior fibers of the temporal, used in closing the mouth. In both cases it is apparent that the mandible will rotate about a point near the attachment of the stylo-mandibular ligament.

First. That the jaw is depressed in ordinary opening of the mouth by the unassisted action of the two external pterygoid muscles, which pull the menisci and condyles forward, make taut the stylo-mandibular, and probably the spheno-mandibular, ligaments, and then rotate the mandible about a transverse axis drawn through the insertion of the ligaments.

Second. That, in *forcible* depression of the mandible, the digastrics assist by preventing too great tension on the stylo-mandibular ligaments, and by drawing the symphysis downward and backward.

Third. That, in trituration, a single external pterygoid advances its condyle, thus giving the lateral motion to the teeth, and, at the same time, slightly opens the mouth; and reversing this, that is, when the actual process of chewing begins, the temporal, masseter and internal pterygoid of both sides, all contract, while the internal pterygoid of the chewing side assists especially in returning the jaw to its original position.

Fourth. That the meniscus, due to its shape and peculiar motion in opening of the mouth, practically obliterates the 'working depth' of the glenoid fossa, and at the same time interposes a cushion between jaw and skull in all positions of the mandible.

Fifth. That special fibers of the temporal and masseter muscles help return the meniscus to its position when the mouth is being closed.

Sixth. That, in closing the mouth, due to the insertions of the three pairs of muscles then acting, the rotation of the mandible is still about a point near the insertion of the stylo-mandibular ligaments. And

Lastly. That a probable reason for the persistence of a certain part of the first visceral arch, known as the spheno-mandibular ligament, is to assist the stylo-mandibular ligament, when the mouth is being opened, in fixing the transverse axis of rotation of the mandible.

June 23, 1913.

SOME NEW DISSECTING ROOM FURNISHINGS

RALPH EDWARD SHELDON

Anatomical Laboratories, School of Medicine, University of Pittsburgh

ONE FIGURE

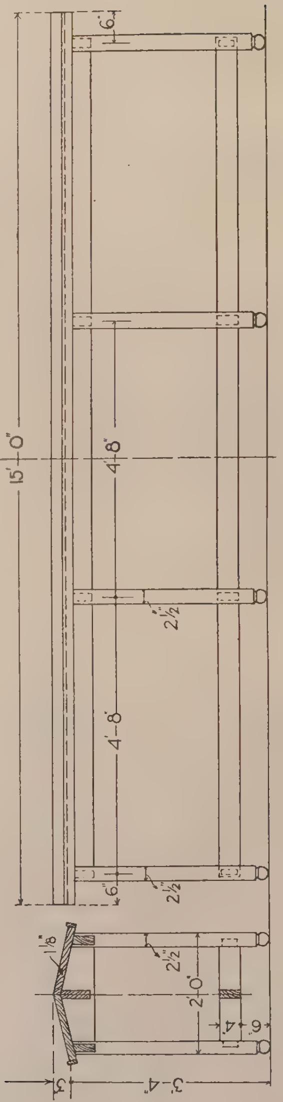
An ever present difficulty in the dissecting room is to provide an adequate arrangement for texts and atlases in every day use, whereby they may be available for students while dissecting. Students desire, naturally, that atlases or other guides be close at hand, so that there be no interruption in their work, and if no satisfactory facilities are provided, they make use of the cadaver, or a corner of the dissecting table. In this case, books become very quickly soiled, and in addition, if several men are working upon the same subject, considerable difficulty is experienced in finding adequate space for books. For these reasons it is very difficult to persuade students to use regularly in the dissecting room the larger text-books and atlases. An alternative, in some laboratories, is to secure small wooden stands, or else some form of collapsible drawing table. Both of these are open to two disadvantages; one is that, as a usual thing, such stands are small, permitting the use of only one volume at a time; secondly, in a large dissecting room with many students, the stands are usually scattered and constantly in the way, taking up a large amount of space if any considerable number of them are used, as at least one such table for each one or two students is needed.

At the University of Pittsburgh we have a single large dissecting room, approximately 45 by 90 feet, and it became necessary, a year ago, to devise stands for books, on account of the purchase by the department, for loan to the students, of a set of Spalteholz' Atlas for each dissecting table. The desks designed and figured herewith, have been in use for a year, and have proved exceedingly satisfactory. Reference to the figures will show form of construction. Each book rack is 15 feet long, 2 feet wide at the base, and 3 feet 4 inches high at the sides. The top has a 3-inch slant toward the dissecting tables at either side, and is provided with a flange to hold books in place. The dissecting tables are placed in rows across the dissecting room, with two of the book desks placed end to end between each two rows of dissecting tables. Room is left for a center aisle and an aisle at either side of the room, and students at a given dissecting table, therefore, have an opportunity to use any part of the rack adjoining their table. It is thus possible for a student to work with his cadaver at one hand, and an open atlas at the other.

Experience shows the advantages of these desks to be as follows: first, since the desks are heavy and difficult to move, they are always in their places during the laboratory period; second, they furnish adequate space for all atlases and other books which the students desire to use; third, all such books are kept clean and in good condition; fourth, owing to these facts, we are able to require the constant use in the dissecting room of the atlases and of the large text-books of anatomy, which we had not been able to do previously; fifth, the tables being of considerable length divide the dissecting room into sections, making somewhat easier the maintenance of order; sixth, the use of such tables improves greatly the appearance of the ordinary dissecting room.

Desks of this size and form, made of solid ash, smoothed and varnished, are very reasonable in price, being delivered to us at a cost of fourteen dollars each.

Acknowledgment should be made to Mr. E. B. Lee, architect, Pittsburgh, for the drawings presented herewith.



BOOK RACK FOR DISSECTING ROOM

THE TRACHEALIS MUSCLE. ITS ARRANGEMENT AT THE CARINA TRACHEAE AND ITS PROBABLE INFLUENCE ON THE LODGMENT OF FOREIGN BODIES IN THE RIGHT BRONCHUS AND LUNG

WILLIAM SNOW MILLER

Anatomical Laboratory of the University of Wisconsin

SIX FIGURES

According to Galen, the posterior wall of the trachea, where it is contiguous with the esophagus, is membranous in order that the esophagus may easily dilate, without compression, when large pieces of food are swallowed. This Galenic idea of the function of the membranous portion of the trachea seems to have been retained as late as the latter part of the eighteenth century; for I find in a 'System of Anatomy,' compiled in 1795 for the use of Monro's students at Edinburgh, the following:

> The trachea consists of segments of circles or cartilaginous hoops, disposed in such a manner as to form a canal open on the back part, the cartilages not going quite round; but this opening is filled by a soft glandular membrane, which completes the circumference of the canal; but this cannot be to give way to the esophagus, for, instead of descending immediately upon the middle of the canal, the trachea inclines a little to the right side, and the same structure is found in the back part of the great bronchial vessels, which are at some distance from the esophagus.

The first part of the above quotation is a literal translation from Winslow, while the last part is evidently a comment made by the compiler or, possibly, a statement made by Monro in his lectures. That there may be some element of truth in this Galenic idea, is possible; for the most frequent seat of carcinoma of the esophagus is the middle third, where it bends somewhat to the left and is situated between the aorta and the beginning of the left bronchus which presents its cartilagenous wall, rather

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than its membranous portion, towards the esophagus. The esophagus itself diminishes in diameter in this region and its mucosa would, therefore, be more subject to abrasion at this point during the act of deglutition and to continued irritation following the abrasion.

The trachea is situated anterior to the esophagus; it extends from the intervertebral disk between the VI and VII cervical vertebrae to its bifurcation into the right and left bronchi, which takes place at the IV or V thoracic vertebra. It consists of a framework of horseshoe shaped cartilages united with each other by a dense areolar connective tissue and lined on the interior with a tunica mucosa. Posteriorly, where the cartilage is wanting, the trachea is flattened. Between the external fibrous tunic and the mucosa, bundles of smooth muscle are found connecting the free ends of the cartilages with each other.

Cuvier seems to have been the first to describe the tracheal muscle as being, in some animals, inserted on the outer surface of the cartilages, in other animals, on the inner surface of the cartilages. After a careful analysis of the published cases, in connection with some of my own studies, I fail to find any assignable cause for the variation. With Meckel and with Luschka, I have found in all the carnivora that I have examined that the attachment is external. In monotremes and insectivora the attachment is internal. In animals that live on a vegetable diet the attachment is, as a rule, internal. In the ox the attachment is internal, but in the rabbit it is external. In man, with a mixed diet, the attachment is internal.

Guieysse has also studied this varied attachment of the tracheal muscle and likewise failed to find any reason for the variation.

If a freshly removed trachea with the bronchi attached be placed for thirty-six or forty-eight hours in Ranvier's alcohol, at the end of that time the epithelium can be easily brushed off from its inner surface and much of the connective tissue removed from its outer surface.

The anterior half of the trachea and of the bronchi should now be cut off, dividing the carina as near its center as possible. The posterior half is placed in 50 per cent glycerine to which sufficient picro-carmine has been added to give it a dark red color. It should remain in this mixture until it is stained a uniform red. When this has taken place the specimen is passed through glycerine of increasing strength until it is in pure glycerine; here it can remain indefinitely.

The specimen is next transferred to a compressor and gradually flattened. It may be found necessary to dissect off the greater part of the connective tissue over the outer surface of the trachea, in order that the muscle may be brought clearly into view. In very thick tracheae, as, for example, the adult human trachea, I have found it necessary at times to remove in the same manner the submucosa from the inner surface before a clear view of the muscle could be obtained.

While passing through the various grades of glycerine any excess of stain is removed and the specimen becomes clear and transparent, and the musculature can be studied under high, as well as under low, amplification.

In specimens prepared by the above method the tracheal muscle can be seen spread out in the membranous portion as a layer of branching and anastomosing bands (upper portion of figs. 1, 2, 3 and 5). Through the interstices of this muscular network pass the ducts of the glands situated external to the muscle, nerves and numerous blood vessels.

In the majority of cases the network formed by the muscle is quite compact. The musculature of the adult human trachea differs from that of the other tracheae studied; it also differs in the adult from that of the newborn child. In the adult the bands connected with a given cartilage maintain to a greater extent their independence than in the trachea of the newborn child, in which the musculature forms a network similar to that of other tracheae (fig. 5).

The attachment of the muscle may be external as in the cat (fig. 3), or it may be internal as in the case of the guinea pig (fig. 1).

The mode of attachment does not seem to influence the character of the muscular network.

Stirling has described muscle bands, between the cartilagenous crescents, in the trachea of the cat. Both Verson and Frankenhäuser have described scattered bands of muscle as ending in the mucosa of the human trachea; other authors have described bands of muscle ending in the fibrous connective tissue between the cartilages. I have failed to find any endings of this nature. I have frequently found bands of muscle passing for some distance through the intercartilagenous fibrous connective tissue but they invariably terminated in the perichondrium. Examples of this can be seen in the case of the rabbit's trachea (fig. 2). Guieysse says that in the smaller animals the insertion is directly into the perichondrium, but in the larger animals an elastic tendon is interposed between the muscle and the perichondrium. In none of the tracheae studied have I found tendons of insertion. In each instance the muscle could be traced directly to the perichondrium.

Longitudinal bands of muscle have been described by some authors; by others their presence is denied. It seems to me that the statement made by Cramer and by Luschka, that, exceptionally they may be found, explains these opposing statements in a satisfactory manner. The nearest approach to longitudinal bands that I have found in an examination of fifty tracheae, is shown in figure 4. In the twenty human tracheae examined nothing comparable to longitudinal bands was found. Luschka has pointed out that, whenever these bands of longitudinal muscle are present, they are situated behind the transverse bands.

By the contraction of the muscle the ends of the cartilages are approximated and the lumen of the tracheae correspondingly diminished. Because of this diminution in diameter the mucosa is thrown into longitudinal folds (fig. 6) which are more pronounced in the membranous portion of the trachea than in the anterior portion.

Underlying the mucosa is a layer of closely interwoven elastic fibers which run lengthwise along the trachea. Zuckerkandl correlated the longitudinal folds of the trachea with bundles of these fibers. I have been unable to find any relation between the folds and the elastic fibers. The elastic fibers appear in the form of bundles because of the folds; the folds are formed by the contraction of the muscle and the inherent elasticity of the cartilages and not by bundles of elastic fibers.

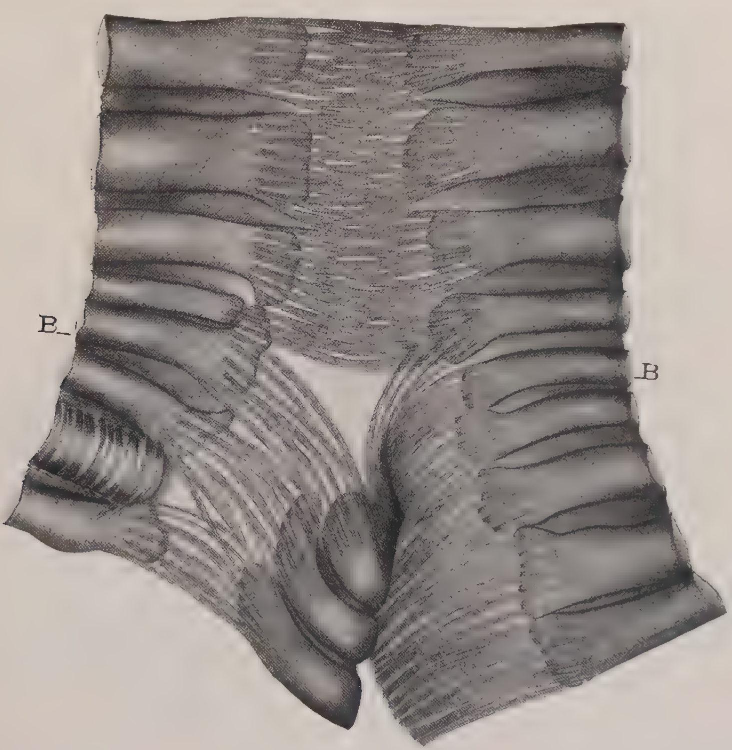

Fig. 1 The arrangement of the trachealis muscle at the carina of the guinea pig. Internal attachment of the muscle. *B*, first bronchial cartilage. The posterior spur triangle is indicated by the clear triangular space. × 10.

If a trachea be divided 25 or 30 mm. above its bifurcation, on looking into the cut end there can be seen running in an antero-posterior direction across the bottom of the trachea, between the two bronchi, a semilunar ridge: the carina tracheae. The margins of the carina diverge as they reach the anterior wall of the trachea and form the lateral boundary of what Heller and

v. Schrötter term the 'anterior spur triangle.' Posteriorly there is also formed a smaller 'posterior spur triangle' which will be described in connection with the musculature.

The carina may be either cartilagenous or membranous. Heller and v. Schrötter found that in about 70 per cent of the tracheae they examined the framework of the spur forming the carina was wholly, or in part, cartilagenous; in the remaining 30 per cent it was membranous. According to the same authors the carina was situated to the left of the midline of the trachea in 57 per cent of the cases, in the midline in 42 per cent and on the right

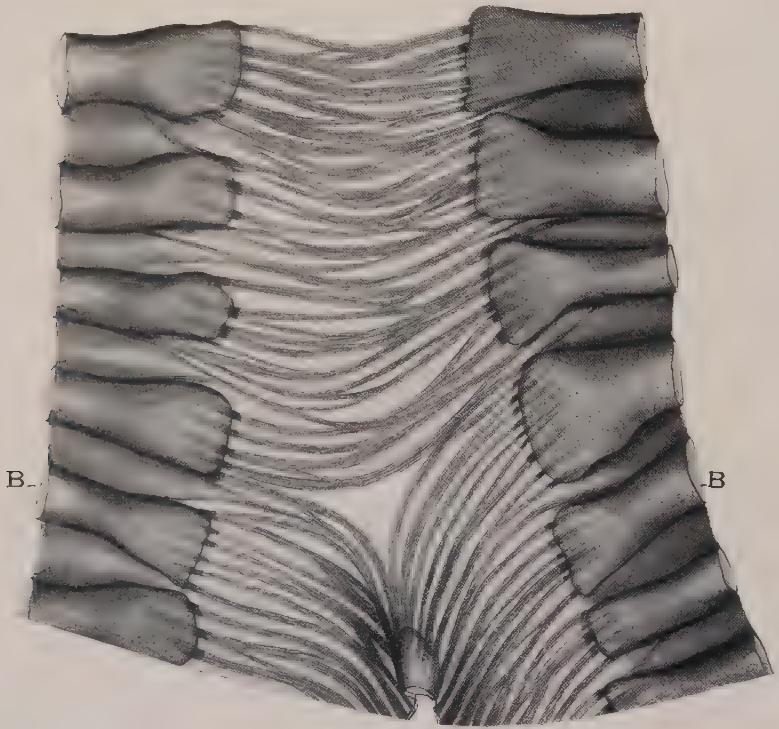

Fig. 2 The arrangement of the trachealis muscle at the carina of the rabbit. External attachment of the muscle. The cartilages are so translucent that the attachment of the muscle can be seen through their free ends. *B*, first bronchial cartilage. The posterior spur triangle is seen as a clear triangular space. × 10.

of the midline in the remaining 1 per cent. McKenzie and Semon found, in 100 living individuals, that the carina was on the left of the midline in 59 cases, in the midline in 35 cases and on the right of the midline in 6 cases.

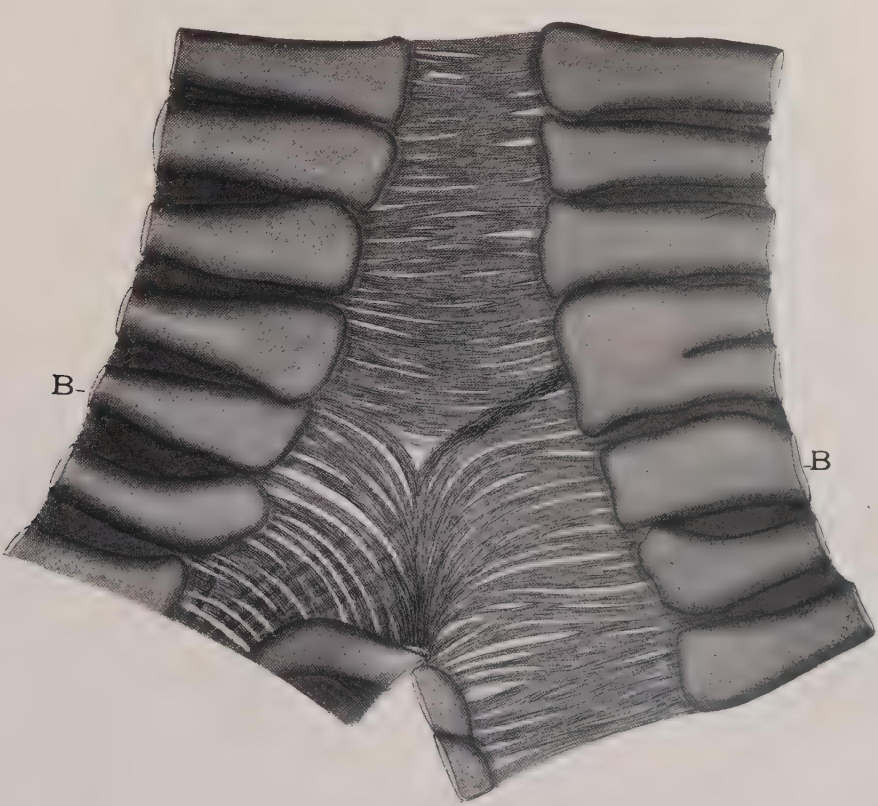

Fig. 3 The arrangement of the trachealis muscle at the carina of the cat. External attachment of the muscle. *B*, first bronchial cartilage. The posterior spur triangle is indicated by the small clear triangular space. × 5.

Under normal conditions the carina has, on cross section, a wedge shaped outline and is situated, as has been shown, to the left of the midline. It also has a rhythmical movement synchronous with the respiration. Anything which interferes with this movement causes the carina to flatten and, in case patholog-

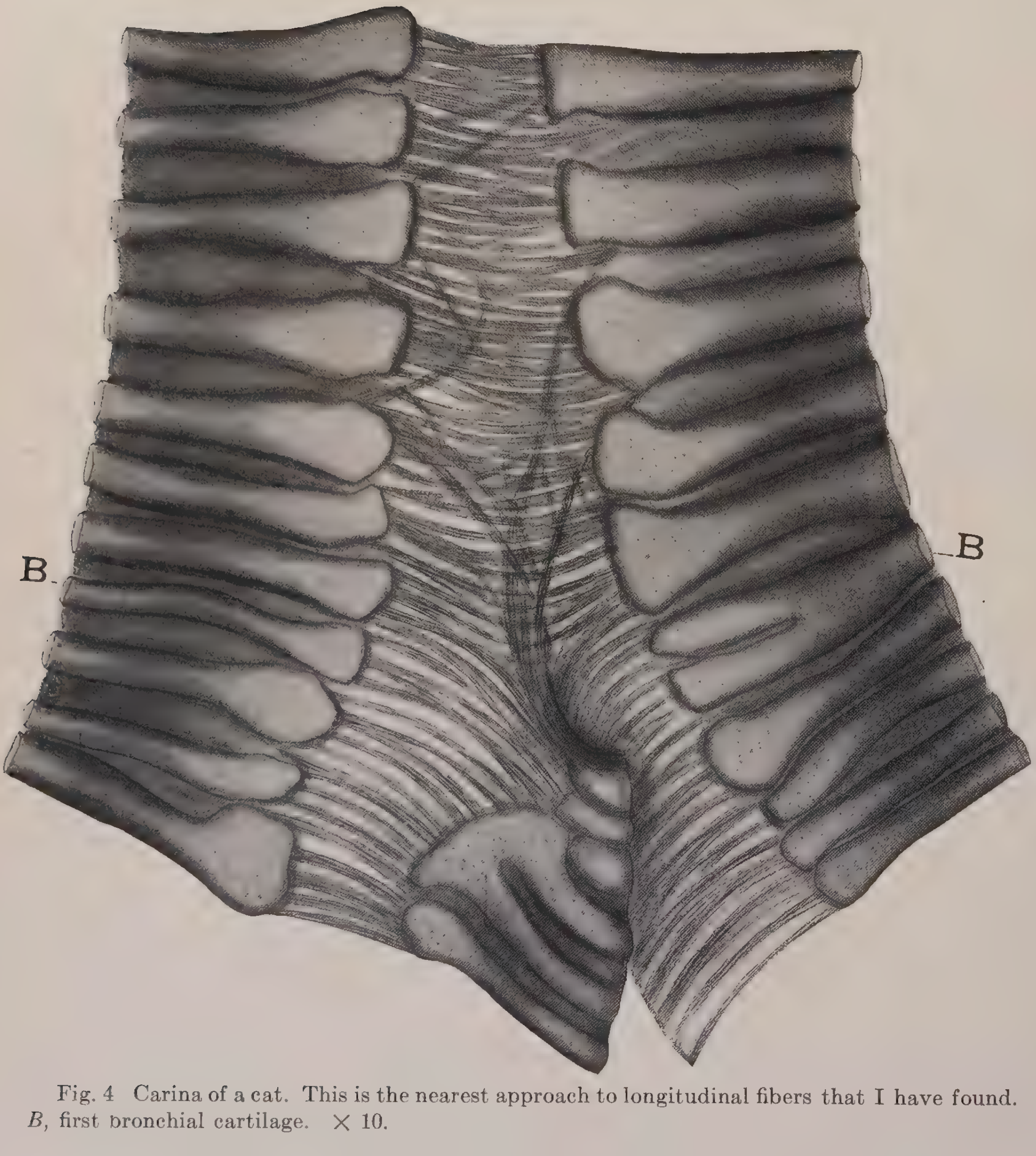

Fig. 4 Carina of a cat. This is the nearest approach to longitudinal fibers that I have found. *B*, first bronchial cartilage. × 10.

ical changes take place in its immediate neighborhood, it may be pushed into the midline or even over to the right side. It is possible that this fact has been overlooked in studying the position of the carina and many of the midline and right side cases are in reality pathological.

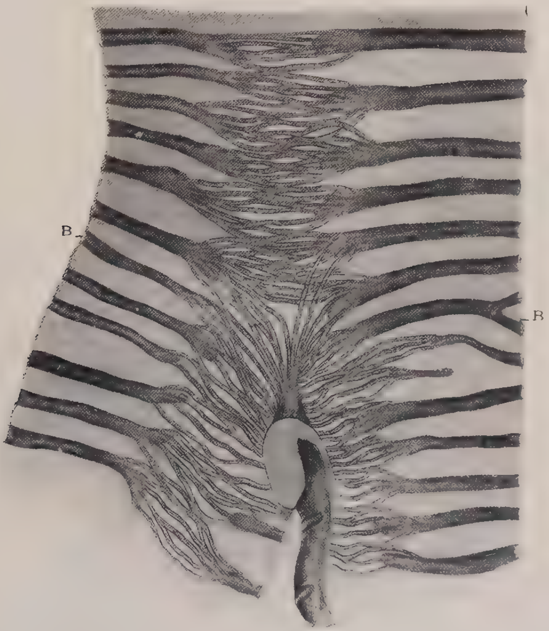

Fig. 5 The arrangement of the trachealis muscle at the carina of the newborn child. Internal attachment of the muscle. *B*, first bronchial cartilage. The posterior spur triangle is crossed by two bands of muscle. × 5.

The importance of this left side situation of the carina, taken in connection with the more direct continuation of the trachea by the right bronchus, to the lodgment of foreign bodies in the right bronchus and the right lung was first clearly brought out by an American surgeon, S. D. Gross.

Preobraschensky has shown that 41.6 per cent of foreign bodies lodge in the larynx; 35.8 per cent in the bronchi and 22.6 per cent in the trachea. According to the same author 69 per cent

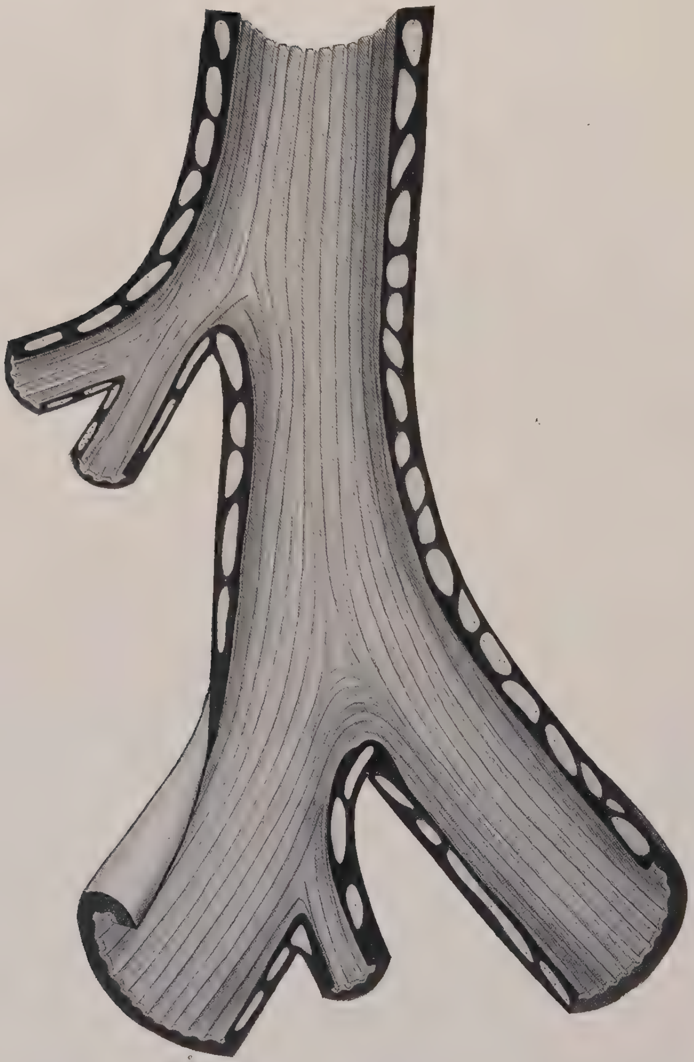

Fig. 6 Posterior half of a trachea of a newborn pig. Shows the rugae formed by the contraction of the muscle. Note the tracheal origin of the right eparterial bronchus. The posterior spur triangle is seen just above the carina as a small white triangle. × 5.

of foreign bodies entering the bronchi, lodge in the right bronchus. Gottstein gives a still higher figure for the right bronchus: 75.4 per cent.

The angle of divergence of the two bronchi also plays an important part in this right side lodgment of foreign bodies; it being for the right bronchus 25.6 degrees and for the left bronchus 48.9 degrees. These figures represent the average of the twenty tracheae measured by Kobler and v. Hovorka. Gottstein states that, in the first year of childhood, foreign bodies are only found in the right bronchus and asserts that this is due to the fact that in children the course of the right bronchus is straighter than in adults. I question this last statement. The few measurements I have been able to make show practically no difference between the two.

While the position of the carina, the presence or absence of cartilage in the carina and the angle of divergence of the two bronchi have received special consideration, the arrangement of the musculature at the carina has been neglected. So far as I have been able to ascertain, Luschka is the only one to mention the presence of special bands of muscle at the carina; he fails, however, to give a detailed description of their arrangement.

The following account is based upon a study of the trachea of the guineapig, the rabbit, the cat, the newborn child and the adult man. The external or internal attachment of the muscle to the cartilages of the trachea does not seem to influence its arrangement at the carina. We have seen that, in the adult human trachea, the muscle attached to any given cartilage maintains to a very considerable degree its independence, differing in this respect from that of the newborn child. As the carina is approached, however, the bands of muscle belonging to the last three or four tracheal cartilages form a network similar to that in the child and in the other forms studied.

Extending from the posterior portion of the carina are diverging bands of muscle which are attached to the extremities of the last tracheal cartilage and, in the case of the left bands to the last two, or even three, tracheal cartilages. By the divergence of these bands of muscle and the transverse bands of muscle connected with the last tracheal cartilage, there is formed a triangular area of variable extent, free from muscle, which corresponds to the 'posterior spur triangle' of Heller and v. Schrötter (fig. 1). The higher attachment of the left bands of muscle is a constant factor and is brought out in figures 1, 2, 3 and 5.

These carinal bands are situated internal to the musculature of the trachea whenever they cross it. This holds true for both external and internal attachment of the tracheal muscle to the cartilages. In tracheae in which the attachment of the muscle was external the carinal muscle was found in a few instances to be attached to the end of the cartilage; in one instance a band was inserted on the inner surface of the cartilage. In all other cases the insertion of the carinal muscle followed that of the tracheal muscle.

In no instance was a tendinous insertion of the muscle into the carina found, although Luschka describes such insertion. In all the tracheae studied the carina was cartilagenous; a membranous carina was not found in the series. This was unfortunate, for it is quite possible that in a membranous carina the insertion is by means of a tendon as Luschka has described.

The important relation of the left side situation of the carina and the more direct continuation of the trachea by the right bronchus to the lodgment of foreign bodies in the right bronchus and lung was, as already mentioned, emphasized by Gross and has been repeatedly confirmed by subsequent investigators. Moreover, in inspiration, the current of air is stronger in the right bronchus than in the left, since the right lung receives a larger amount of air in a given time than the left lung.

To the above factors can be added the arrangement of the musculature at the carina which must, by its action, draw the carina to the left and at the same time reduce the lumen of the left bronchus facilitating in this manner the passage of any foreign body into the right bronchus and lung.

The right lung is more subject to pathological processes than the left lung. Primary carcinoma of the lung is more frequent in the right than in the left lung. Pneumonias also occur more frequently in the right lung than in the left lung in the proportion of seven to three, and the lower right lobe is more frequently affected than other portions of the lung. It appears not improbable that the above factors which make the right lung more accessible than the left play an important rôle in the preponderance of diseases of the right lung.

BIBLIOGRAPHY

CRAMER, H. 1847 De penitiori pulmonum hominis structura. Berlin.

CUVIER, G. 1810 Vorlesung über vergleichende Anatomie. Meckel's translation.

FRANKENHÄUSER, C. 1879 Ueber den Bau der Tracheo-Bronchialschleimhaut. St. Petersburg.

GOTTSTEIN, G. 1907 Ueber die Diagnose und Therapie der Fremdkörper in dem unteren Luftwegen, mit besonderer Berücksichtigung der Bronchioskopie und Radioskopie. Mittg. a. d. Grenzgeb. d. Med. u. Chir. Supp. Bd.

GROSS, S. D. 1854 A practical treatise on foreign bodies in the air passages. Philadelphia.

GUIEYSSE, A. 1898 Sur quelques points d'anatomie des muscles de l'appareil respiratoire. Jour. de l'Anatomie et de la Physiologie. Année 34.

HELLER und v. SCHRÖTTER. 1897 Die Carina Tracheae. Denksch. d. Math.-Naturw. Klasse d. kais. Akad. d. Wiss..

KOBLER und v. HOVERKA. 1893 Ueber den Neigungswinkel der Stammbronchi. Sitzb. d. kais. Akad. d. Wissensch. Wien. Math.-Naturw. Klasse. Bd. 102.

LUSCHKA, H. 1862 Die Anatomie des Menschen. Tübingen.
1869 Die Muskulature der Luftröhre des Menschen. Arch. f. Anat. u. Physiol. Bd. 14.

MECKEL, J. FR. 1833 System der vergleichden Anatomie. Halle.

PREOBRASCHENSKY, S. S. 1893 Ueber Fremdkörper in den Atmungswegen. Wiener Klinik.

STIRLING, W. 1883 The trachealis muscle of man and animals. Jour. Anat. and Physiol., vol. 17.

VERSON, E. 1871 Kehlkopf und Trachea. In "Stricker's Lehre von den Geweben." Leipzig.

WINSLOW, J. B. 1732 Exposition anatomique de la structure du corps humain. Paris.

ZUCKERKANDL, E. 1898 Anatomie und Entwickelungsgeschichte des Kehlkopfs und der Luftröhre. Handb. d. Laryngol. u. Rhinol. Wien.

THE LEGAL STATUS OF DISSECTING

GEORGE B. JENKINS

From the Anatomical Laboratory of Johns Hopkins University

At the suggestion of Dr. Mall[1] I have endeavored to collect all the data obtainable concerning the question of dissection; considering the laws regulating the supply of material, the sources from which such material is usually obtained, the character, that is, the age and sex of the subjects, how preserved and transported, and such other details as could be obtained that would be of value.

One is struck by the fact that it has been only comparatively recently that any laws have been enacted upon this important subject. Prior to that time the various states, chartered, or otherwise recognized numerous medical colleges, anatomical schools, and such, but made no legal provision by which they could secure material for dissection, demonstration, and so forth, and as such material was indispensable, various questionable means were employed to secure it, such as 'body-snatching' and 'grave-robbing.' As the demands grew, competition became so sharp that these methods were not only widely practiced, but through connivance with those having charge of bodies, many people paid their last tribute of sorrow over an empty grave. This keenness of competition further led to an increased cost of bodies; so one thing led to another until even graver crimes than those mentioned were perpetrated. These obnoxious practices finally became intolerable to the more advanced men, who saw that such things were bringing medical schools and medical teachers into disrepute with the public. So the more progressive of these men took steps to secure the enactment of such laws as would secure to legitimate schools a supply of material from among the unclaimed pauper dead, thus eliminating objectionable practices and at the same time assuring a supply of the needed material. The names of such men as Forbes[2] and Keen[3] of Philadelphia and Mall[4] and Smith of Baltimore are prominently identified with the initiation of this new era. From this nucleus the influence has gradually spread until at the present day but few states remain which have not taken some steps to legalize the use of certain classes of material for educational purposes. A curious fact appears, that in all this period in which material was scanty, difficult to procure, and impossible to keep more than a few days, they never seemed to supplement such dearth by the use of the lower animals for gross dissection, for after the days of the earlier anatomists[5] one finds only one or two instances where animal tissues were used save for histological studies, which was generally introduced as a part of the anatomical course only a few years ago.

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[1] I am indebted to Dr. Mall for numerous suggestions, to Drs. Keen and Hewson of Philadelphia for data, and to Mr. A. H. Mettee, Librarian of the Baltimore Bar Association, for courtesies extended.

In order to secure the necessary data, a question form was sent to the legal department of each state relative to the existence of such laws and their provisions. Another form was sent to a majority of the medical colleges, inquiring as to how such laws met their needs concerning the quantity and character of such material. To save unnecessary repetition the District of Columbia has been classed as a state.

Forty-nine letters were sent out to the attorneys-general of as many states. Of this number seven—Arizona, Florida, Idaho, Montana, New Jersey, Rhode Island, Wyoming—did not reply. Replies were received from the majority of the remaining forty-two; the rest were checked in the Baltimore Law Library. The seven mentioned above have never had any medical schools, consequently it was not thought necessary to include them in this résumé. Of the forty-two which are reviewed, five—Alabama, Delaware, Louisiana, Nevada and New Mexico—have never passed any laws upon this subject. Of these Alabama and Louisiana both have medical colleges, the former as an integral part of the state university, the latter an endowed university. This leaves then thirty-six states to consider in this summary. A critical study of the various laws in effect in these states brings out the following interesting points:

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[2] W. S. Forbes, History of the Anatomy Act of Philadelphia; Philadelphia Medical Publishing Company, 1898.

[3] W. W. Keen, Addresses and Other Papers; W. B. Saunders and Company, 1905.

[4] F. P. Mall, Anatomical Material; Johns Hopkins Hospital Bulletin, vol. 16, 1905.

[5] C. R. Bardeen, History of Anatomy; University of Wisconsin Press. Further information concerning the early history of Anatomy can be obtained from such works as the Life of John Hunter, Life of Sir C. Bell, Letters and papers of Sir Astley Cooper, Letters and papers of Wm. Hunter, Life of Robert Knox, etc.

In only thirteen states—District of Columbia, Georgia, Indiana, Maine, Maryland, Missouri, North Carolina, Pennsylvania, Texas, Virginia, South Carolina, Minnesota, West Virginia—is provision made for the establishment of an anatomical board, an exceedingly desirable feature since this board formulates all necessary rules, governing the preservation, reception, transportation, and keeping of material for identification, its proper distribution to colleges when there are more than one in a state, and seeing that proper records of all material are kept, bonds given, and so forth. In the thirteen states mentioned, the law specifies that the material provided shall be turned over to this board or to its representative. The others name as recipients, medical and dental colleges, physicians, or medical students studying under physicians. Some are not as specific as they should be. Arkansas, for example, gives bodies to any physician or medical student—not using the term 'college' and yet there is a medical school connected with the state university. Three states specify a single college; Utah, its state university; Connecticut, Yale Medical School; and Mississippi, its state university, when only recently another medical school was maintained at Meridian, Mississippi, in addition to the university. Two states, Michigan and New York, specify that material from a given locality must be given to the schools located in that locality. In one state, Maryland, a large city and the county in which it is situated are named as the sole territory from which material may be secured.

As to what material is made available for use, we find the usual lack of harmony. In two states—North Carolina and Tennessee—the only material named is the bodies of such criminals as die while under sentence in penal institutions. In only seven states are all unclaimed dead allowed without due reservation. These states are Iowa, Kentucky, Mississippi, Oregon, New York, Michigan and Minnesota. The remainder allow all unclaimed dead which would require burial at public expense. The exceptions made to this provision in many states are so numerous and the allowance of claim by friends or relations so pronounced that a great deal of material is thereby needlessly lost. Minnesota, in addition to the exceptions noted, includes all criminals and those held as witnesses as material not to be used. In two states, Mississippi and North Carolina, the body of a Confederate soldier is excepted. In the latter state the wife of such a soldier is added. This state further provides that the body of no white person shall be sent to a negro medical college. Three states—Massachusetts, New Hampshire and Vermont except the bodies of those who have served in the army or navy. Sixteen states except those who make an ante-mortem request for burial—Arkansas, California, Colorado, District of Columbia, Connecticut, Iowa, Kansas, Mississippi, Oregon, North Dakota, Oklahoma, New York, Vermont, Washington, Wisconsin and Minnesota. This provision undoubtedly withdraws a vast amount of legitimate material from the field of usefulness. It would seem that when the state had at public expense cared for the individual during his last illness, the body, unless buried by relatives and at their expense, should certainly be given where it could be used for public good rather than become a further expense to the public. Under the exception of relatives and friends twenty-two states—Arkansas, California, Colorado, Connecticut, District of Columbia, Georgia, Illinois, Iowa, Kansas, Kentucky, Mississippi, Massachusetts, Missouri, New York, New Hampshire, Ohio, Oklahoma, North Dakota, Oregon, Virginia, South Dakota and Utah—specify that any friend may claim and receive bodies. Of these only nine—District of Columbia, Kansas, Georgia, Illinois, Massachusetts, New York, Pennsylvania, South Carolina and Vermont—require the claimant to furnish proof to sustain his claim, and only four require the claimant to bear the expense of the interment; these are Missouri, New Hampshire, Ohio and Utah. Eighteen except 'any stranger or traveler who died suddenly;' these states are Arkansas, Connecticut, California, Colorado, District of Columbia, Georgia, Maryland, Mississippi, Massachusetts, Oklahoma, Ohio, New Hampshire, Pennsylvania, Virginia, Vermont, Washington, Wisconsin and South Carolina, and of these but two, Connecticut and New Hampshire, state that the genus commonly known as tramps, are not included within the exceptions. This last makes possible a large number of bodies which next to criminals perhaps would seem to be those most desirable to be used since in but few instances could these even be claimed by friends. It is probable though that in effect, this, like many other provisions, is not as bad as it seems from the letter of the law.

On the other hand, only eight states—Georgia, Illinois, Kansas, Nebraska, Texas, Utah, Wisconsin, and West Virginia—specifically state that due notice of death must be sent to relatives or friends of deceased individuals which come under control of the officers of the various public institutions—at least such provisions were not included in the sections covering anatomical material. Yet twenty states require the persons or institutions having charge of such bodies to keep them for a specified time for purposes of identification by such relatives and friends as appear; these states are: Kentucky and Massachusetts, requiring three days; Nebraska, New York, Vermont, Washington and Wisconsin, requiring forty-eight hours; Michigan, Minnesota, New Hampshire, North Dakota and Ohio, requiring thirty-six hours; Arkansas, Connecticut, California, Colorado, District of Columbia, Georgia, Kansas and West Virginia, requiring twenty-four hours. The remainder make no provision for such save in Mississippi, which states "when said body is not claimed for burial within a reasonable time after death," etc. Some states further require the college or other recipient to keep the body, subject to claim, for an additional period of time. Of these, four—Georgia, Iowa, South Dakota, and Utah—require that a body be kept sixty days; Kentucky requires thirty days; Massachusetts fourteen days, and Texas requires ten days. Only seven states require that a history be sent with the body. These are the District of Columbia, Kansas, Mississippi, Missouri, Nebraska, South Dakota, and Utah, and this history is only such facts as may be needed for identification. None add the desirable feature of a medical history which would be of so much value for anatomical as well as pathological study. Only sixteen further require that any record be kept by those receiving the body. These are the District of Columbia, Indiana, Iowa, Kansas, Kentucky, Mississippi, Missouri, Nebraska, New York, Pennsylvania, South Dakota, Texas, Utah, South Carolina, Michigan and West Virginia.

Eleven states—Connecticut, District of Columbia, Illinois, Michigan, Mississippi, Missouri, Pennsylvania, Texas, Utah, Wisconsin, and West Virginia—fix upon the recipient the cost of preparation, transportation, and so forth, of the body. In only seventeen states—Colorado, Georgia, Illinois, Indiana, Kansas, Kentucky, Maryland, Massachusetts, Maine, Nebraska, North Dakota, New Hampshire, Pennsylvania, Texas, Washington, South Carolina, and West Virginia—is any bond required of those receiving that such material will be used in such manner and for such purposes as are specified in the acts.

Material for dissecting purposes may not be taken beyond the limits of the state in twenty-four instances, namely, Arkansas, Colorado, District of Columbia, Georgia, Illinois, Indiana, Iowa, Kansas, Maryland, Massachusetts, Oregon, Nebraska, North Dakota, Oklahoma, Ohio, New Hampshire, South Dakota, Pennsylvania, Utah, Virginia, Vermont, Michigan, Wisconsin, and West Virginia. Yet two states, South Carolina and Virginia, make provision for the importation of material in case of need. All but five states in this summary, Connecticut, South Carolina, Michigan, Minnesota, and Tennessee, specify in varying language that such material as provided shall be used solely for educational purposes. Twenty-one states specify the manner of disposal of remains of bodies after dissection. Of these Arkansas, Colorado, District of Columbia, Georgia, Iowa, Kentucky, Mississippi, Massachusetts, Oregon, Ohio, New Hampshire, South Dakota, Virginia, Washington, South Carolina, Michigan, and Minnesota require their burial; while Illinois, North Dakota, and Utah allow the option of cremation; and New York specifies that such shall be according to the order of the local board of health. In only six states is any mention made of such of these bodies as have died of infectious diseases. In five of these—Connecticut, Georgia, Indiana, Texas, and Ohio—they are prohibited using them, while Wisconsin allows such of these to be used as may be further allowed by the state board of health, and after such disinfection, and so forth, as these authorities may require.

The majority of these states specifically name all those who have charge of such material as could be used and are reasonably mandatory as to the provision in the various acts, thus giving the option to the recipients of all the territory within the bounds of the state, subject to the exceptions above noted.

Sixteen states specifically provide a penalty for such as refuse to surrender to the proper persons such bodies as may be in their charge. These are the District of Columbia, Illinois, Indiana, Kentucky, Kansas, Maryland, Missouri, Nebraska, North Dakota, New Hampshire, New York, Pennsylvania, Utah, Vermont, South Carolina, and Michigan. Twenty-four states provide penalties of varying degrees of severity (most are fines or imprisonment or both) for failure to comply with the provisions of the acts. These states are the District of Columbia, Georgia, Illinois, Indiana, Iowa, Kentucky, Kansas, Maryland, Missouri, Oregon, North Dakota, Oklahoma, Ohio, Nebraska, New Hampshire, New York, Pennsylvania, Virginia, Vermont, Washington, Wisconsin, South Carolina, Michigan, and West Virginia. In only ten is the unlawful handling of dead bodies a punishable offense. The District of Columbia, Georgia, Illinois, Iowa, Nebraska, Oklahoma, Pennsylvania, Vermont, Washington, and Tennessee, all provide penalties for this practice, and in only one of these, Iowa, is the punishment especially severe.

In but very few of the states are the laws so drawn as to prevent easy evasion, and in practically none of them are all desirable points included, and all would be benefited by a thorough revision and standardization that all available material within the given state may be subject to the need of the schools in that state, and that such material may be proprly prepared, transported, and otherwise handled according to the best methods under existing conditions. For vast differences will be found in the requirements of moist and dry climates and the high temperatures of the far south, and the low ones of the extreme north, so sufficient latitude could be allowed the anatomical board in handling such matters. Again, a member of the state board of health should be also a member of the state anatomical board as should a representative from the attorney-general's office, so that the one could see that all matters bearing upon public health could be adequately cared for and that legal advice and aid could be secured to the board upon need. It is also desirable that it be made possible to secure fresh material for histological needs. This could be accomplished by giving to the board the bodies of all who are legally executed under the state laws. This is at all possible, in only four states—Connecticut, Colorado, Massachusetts and Oregon—and they do not add the desirable clause making the body accesssible immediately after death, as it should be. Adequate provision should be made in all states for punishing all offenders, especially those who engage in unlawful practices, such as grave-robbing, and so forth. Bond should be uniformly required of those receiving the body, and a complete record including a medical history of the deceased should be kept both by the institution in which he died and by the final recipient. Some provision should be made as to autopsied material, since most schools receive a large amount of such only partially useful material, and in only one state is this specifically guarded against, namely, Missouri, which provides that it is unlawful for anyone to hold an autopsy upon any of the bodies coming under the head of anatomical material without the "written telegraphic or telephonic consent of the secretary of the board." This is also the interpretation of the law in Maryland. Some such simple provision as this would assure a greater quantity of valuable material for school use.

We will now turn to the consideration of the statements from the various medical colleges as to how these laws have met their needs regarding the character and amount of material, as well as the difficulties in the way of securing it. A letter form was sent to the majority of the colleges in the United States, and answers were received from fifty-five colleges embracing all sections of the country and all grades of the classification of the Association of American Medical Colleges.

The following questions were answered:

1. Is your supply of material adequate to your needs? To this forty-one answered an unqualified affirmative; eight, an unqualified negative; five claim supply barely sufficient for their needs; and one that the supply exceeds the needs of the school.

2. From what sources do you obtain the bulk of material? The answers to this were neither sufficiently full nor explicit to be of much value, and must be grouped to give any satisfactory data. Quite a large majority name alms-houses as the sole or main supply of material. This, of course, presupposes a preponderance of aged persons. Some give tubercular hospitals as the chief source, one claiming that 75 per cent of material received were subjects in advanced stages of tuberculosis. Those located in large cities name the usual charitable institutions, hospitals, and so forth, and thus probaly have a fair amount of both sexes and of all ages. Some secure their material from distant points. In very few instances does it appear that the entire territory available is adequately covered, the reasons for which are only conjecturable in the main, though some specify the reasons which will be given in answer to the last question.

3. What is the character of the material secured? In answer five complain of the poor quality of their material due either to its being kept too long, to imperfect embalming or both. Thirty-four claim their material to be good or excellent. One that it is 'very fine.' The remainder procure indifferent material. One state university writes that most of the bodies received have been autopsied. Further, eighteen frankly state that the bulk of their material consists of adult males, and practically none of

them have sufficient adolescent or female bodies, both of which classes are eminently desirable for teaching purposes.

The last question: What (if any) change would you suggest in the law as it applies in your state? is answered by thirty that they desire no change whatever. Seven complain of evasions being practiced to their hurt and desire the law to be more specific, and to have a stricter enforcement. One claims the law is not specific, allowing too much latitude. As yet there has been no law enacted in that state governing this matter. Three have new laws pending before the legislature. The remainder are divided between the complaints that bodies are turned over to claimants too readily, that too many bodies are post-mortemed, and want all institutions in the state included in their list as available for securing material. So we find that an unprejudiced survey of the situation shows apparently at least a need for a general revision of the laws, and then a stricter enforcement of their provisions on the one hand, and a standardization of the methods of preparing and transporting the material as well as a greater activity in securing all available material on the other hand since the above data permits of three wide divisions.

1. States in which there has been as yet no legislation bearing upon these questions, yet in two of which, as has been shown, medical colleges are chartered and in one instance supported.

2. States in which the law as it reads is admittedly inadequate and unsatisfactory or in which by reason of evasion of certain clauses it is bad in effect; as an example of this class, a progressive state like Minnesota, having a splendid educational system headed by a great university, has an anatomical law which is so conflicting and unsatisfactory that the attorney-general admits that he is ashamed to cite it. And many others complain of the evasion of more or less of the provisions by those having the bodies in charge.

3. Those states in which the laws either in letter or in effect are adequate and satisfactory, or possibly because of other reasons those who deal in such material are content to let matters remain as they are. This third class contains the majority of the schools of this country.

It is to be observed that for some reason very few of the schools take advantage of all the material from the entire territory allowed them by law. Some answer this apparently by citing the difficulties and the added expense attached to shipping the material from distant points. One state university (Mississippi) states that the average cost to the school of each cadaver is $25. Think of it, and for poor material at that! Others claim that in these instances the body is poorly prepared and is valueless when obtained. All such features could be easily remedied by adopting adequate laws and requiring their enforcement.

It will be observed that the first question is so framed as to avoid the feature of what constitutes an adequate amount of material in proportion to the number of matriculates. It is perhaps well to allot one or better two whole bodies (i.e., bodies which have not been autopsied) to each student, in addition to others for study room preparations.

In the second question it was desired to show whether the college was limited or limited itself in its range of territory, and to show how well the bodies had been preserved, as well as the age, sex, and so forth.

The answers to the last question may bespeak an indifference in some instances, but in the main are eloquent commentaries upon the difficulties in the way of securing adequate legislation upon necessary matters, when one must steer between the Scylla of greed and selfishness of special interests on the one hand and the Charybdis of prejudice and indifference on the other.

I append here a rough draft of an act which embodies most of the desirable features in the case.

AN ACT TO PROVIDE MATERIAL FOR THE STUDY OF ANATOMY

1. There shall be established an Anatomical Board, consisting of the professors of anatomy of the various medical schools in this state together with the secretary of the State Board of Health and a member of the Attorney-General's office, and within sixty days after the passage of this act, these members shall meet and shall elect the necessary officers from among their

number. It shall be the duty of this Board to receive all such bodies as may be provided for in this act, and to prepare or cause to be prepared such bodies and to distribute them equitably to such schools or colleges wherein the science of anatomy is taught in proportion to the number of students therein. All such bodies as are provided shall be held, prepared, and transported in accordance with the orders of this Board and under the further provisions of this act.

2. It shall be the duty of all officers in charge of all penal and charitable institutions in this state, which are maintained at public expense, to notify said Anatomical Board immediately upon the death of any person that would require burial at public expense, and shall prepare and dispose of such bodies in accordance with the instructions of said board. It shall further be the duty of these officers to hold this body twenty-four hours for the purposes of identification or claim of relatives, making in the meantime every reasonable effort to notify such relatives of the death of deceased inmate. The Anatomical Board shall further cause said body to be kept for a period of thirty days for purpose of identification and claim by authorized persons.

3. It is further provided that the bodies of persons who shall be executed according to the laws of this state shall be and become the property of the state and shall, if it be desired, be given immediately after death to the Anatomical Board.

4. It shall further be the duty of all persons having charge of such bodies as are specified in this act to keep a complete record of all such bodies and a medical history of the same and a copy of such record and history shall be sent with the body, and the Anatomical Board shall keep or cause to be kept a copy of such record for purposes of identification. These records shall be open at all times to the inspection of any prosecuting attorney.

5. The bodies herein provided shall be used only within the bounds of this state, and for the purpose of anatomical study, and the remains after dissection shall then be cremated or buried.

6. It is further provided that all expense incident to the preparation and transportation of these bodies shall be borne by the recipient to whom they are finally consigned.

7. It shall further be the duty of the Anatomical Board to require a bond of one thousand dollars ($1000) of the school or college receiving one of these bodies as provided above in evidence that said body shall be used in the manner and for the purposes stated in this act.

8. There shall further be a penalty for the unlawful handling of the body of any dead person of a fine of one thousand dollars ($1000) or six months in jail or both.

9. Any person found guilty of violating any of the provisions of this act shall upon conviction be fined not less than one hundred dollars ($100) nor more than one thousand dollars ($1000).

ANATOMY: ITS SCOPE, METHODS AND RELATIONS TO OTHER BIOLOGICAL SCIENCES[1]

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In the serial arrangement of the sciences which Comte proposed, the biological group occupies a position intermediate between physics and chemistry on the one hand, and psychology and sociology on the other. Within this group are a number of special subjects, which have arisen as new fields have been cleared, or which have been formed from the subdivision of fields already known. The divisions at present recognized are not, however, natural, but rather are expedients to meet the exigencies of technical methods of study. From this a condition of overspecialization has resulted which is largely artificial.

So it has been with our societies. Actually meeting with us here, there are associations for zoölogy, botany and numerous others devoted to special groups of animals or plants, that is, societies classified according to taxonomics; and there are others based upon the point of view from which natural objects are looked upon: naturalists, anatomists, physiologists and biochemists. While it may be safely assumed that these societies represent some actual segregation of interest, it is perfectly clear that the grouping is factitious and not logical. Furthermore, a survey of the situation soon shows that any thoroughly logical grouping of subjects is impossible. It is very significant, however, that an ever increasing number of individuals are interested in the work of more than one society, which shows that attention is now becoming centered along the borders between the fields. While this often brings inconvenience in attending meetings, it is a condition which all must welcome as tending to counteract the dangers of overspecialization.

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[1] Address of the President delivered before the American Association of Anatomists at Cleveland, Ohio, December 30, 1912.

Anatomy, amongst the biological sciences, occupies a central position; its scope overlaps that of physiology, pathology, zoölogy and psychology, not to consider, for the present, its important applications in practical medicine and surgery. The interests of anatomy and physiology are so intertwined that the two sciences must remain inseparable if their progress is to be fostered. There is perhaps a more natural plane of cleavage between anatomy and pathology, but even the phenomena with which the latter deals cannot be properly interpreted except in comparison with the normal, and on the other hand, every abnormal condition—as Roux has rightly pointed out—is in a certain sense an experiment of nature which may give us an understanding of so-called normal events.

With zoölogy the relations of anatomy are peculiar. In the broad sense zoölogy includes anatomy, but because of the special relations of the latter to man and to the art of healing, and, on the other hand, because of the occupation of zoölogy with natural history apart from man, there have grown up, side by side, two groups of workers, interested largely in problems of animal form, whose cognomens are determined, not so much by subject matter and early training, as by present fortuitous attachments. There are anatomists who study protozoa and coelenterates, and zoölogists who study mammals. Nevertheless, the distinction between anatomists and zoölogists, accidental as it is, will no doubt remain, because of the practical necessity of having teachers to lay before medical students the facts of animal morphology in relation to the structure and function of the human body, as the proper groundwork to the medical sciences. If, however, one examines the programs of the two societies devoted respectively to anatomy and zoölogy, one will be struck by the fact that a more logical arrangement could be made by a partial pooling of interests—not an actual fusion, but a sort of annual conjugation with resulting interchange of nuclear material, followed—if I may be permitted to carry out the analogy according to a view now not beyond question—by rejuvenescence.

The greatest danger to anatomy, strange to say, lies in the very fact of its practical importance. It is this circumstance that in England and America has threatened, and even now threatens, to make the science entirely subservient to practice. This has been felt both in teaching and in research. Teaching has been mainly a drill and an exercise in the details of dissection, and the manner in which even embryology and histology are usually presented, does not altogether alleviate the situation. Admitting that some of the drill is necessary and that it has, at least, the merit of inculcating a certain spirit of thoroughness and mastery of detail, it cannot be gainsaid that it is but to dull the intellect of the student if the power of reasoning is subordinated to the memory drill, and the broad general bearings of the subject are allowed to be overshadowed by the purely practical ones. Several past presidents of this Association have dwelt upon these evils, which are now pretty generally recognized, but they still exist, and we are now confronted with the problem how anatomy may maintain its high standing as an intellectual pursuit, and avoid the fate of becoming a mere handmaid to practice. Is anatomy contributing to the intellectual development of biology and medicine in the same measure as it has in the past? Leaving aside the matter of teaching, can the current lines of research continue dominant without soon leaving the science a finished subject of historic interest only? We must not be oblivious to the fact that anatomy is surrounded by other sciences, and that these, by availing themselves of new methods, are forging ahead by leaps and bounds, at the same time encroaching upon and nearly covering the field rightly anatomy's own.

The past generalizations of anatomy were great achievements. By giving us a clear insight into the arrangement of the parts of the body through an array of definite tangible facts, it has done more than any other science to banish superstition and mysticism from medicine. It has given us the concept of homology or morphological equivalence and thereby brought order out of chaos in the matter of describing and classifying organisms. In the cell theory, as modified by Virchow and Max Schultze, anatomy has made a generalization of first magnitude by giving a descriptive term applicable to all parts of all organisms, whether normal or diseased. By its accomplishment in the field of development it has related these achievements to one another, enabling us to formulate with precision the great problems awaiting solution.

But a science, like a community, cannot live solely by its past. New ideas alone will suffice to keep it from stagnation. To fill in the details of descriptive anatomy, histology and embryology, is not a sufficient task to keep our wits sharpened. Nor will such things longer command the interest of our co-workers in biology and medicine, and to become a bore is to lose influence.

The purely morphological conception of anatomy which became fixed after the period of Johannes Müller has led us to a barren field where we are still plodding, as Loeb[2] has recently set forth in admirable manner. Leaders like Max Schultze and His strove to keep the science in the right course, and later it seemed that the physiological morphology of Nussbaum and Loeb, and the developmental mechanics of Roux, Pflüger and Born, would become predominant over the study of homologies, but it has not been so to the extent to be desired. These movements have been of wide significance, but their influence has fallen in greater measure upon zoölogy than upon anatomy. Examine the proceedings of the last meeting of the Anatomische Gesellschaft—that society to which we all look for leadership—and you will not find a single paper on experimental or physiological morphology, excepting only several demonstrations by visitors from over the sea.

During this purely morphological period our science has occupied itself with genealogy, with painstaking descriptions of the organs, with examining the minutest structural details of precipitated protoplasm, and with stereotyping stages of the developing embryo, but it has left the problems of the living organism, to a large extent, in the hands of its competitors, zoölogy, physiology and pathology.

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[2] On the teaching of anatomy. Anat. Rec., vol. 5, 1911.

A simple enumeration of some of the problems rightly our own, which are awaiting solution, will serve to impress their extent and manifoldness upon us, and should awaken us to our vast opportunities:

First, there is the field of individual development, with its intricate interactions, including the problems of movement, division, segregation, and differentiation of cells, and the problems of growth and senescence.

Secondly, the problems of regeneration and form regulation, which are fundamental and even more baffling than those of embryonic development.

Thirdly, a field almost entirely neglected by us, but one that we must consider on account of its practical as well as its theoretical importance—the problems of genetics or transmission of characters from generation to generation, including causes of variation and its study by statistical or analytical methods, rather than by mere description of individual cases.

Lastly, the correlation of structural mechanisms and changes therein with functional activity, a field which includes a long list of problems, apparently widely divergent, from the mapping out of reflex mechanisms to the localization of chemical processes in the cell.

Anatomy must, in short, busy itself with all phases of the problems of organic form. It will be found that they are as fundamental as, and perhaps even more recondite than, are the problems of function. Recent opinion on the origin of life, serves but to show how supposedly fundamental distinctions, as to function, between living and non-living matter fade when subjected to close scrutiny, and it may well turn out that the morphological quality of specific form with heterogeneity of material, arising gradually from a relatively simple germ, is after all the most peculiar property of living matter. We may be able, some day, to understand the exact workings of the mechanisms of the animal body, at least in the same sense that we understand the mechanisms of a steam engine, while the great problem of development still remains a riddle. Organic form is the product of protoplasmic activity and must, therefore, find its explanation in the dynamics of living matter, but it is the mystery and beauty of organic form that sets the problems for us. Structure is a product of function, and yet at the same time, is the basis of function. The activities of an organism may be nothing more than the continuance of those changes that produce development.

It is often said, however, and I fear usually by way of reproach, that anatomy is a science of statics while physiology is one of kinetics. The methods at present in vogue in anatomical research, have furthered this idea, though nothing could be more subversive of a true conception of organic form than to regard it as fixed. A statical organism can only be a dead organism, embalmed or in cold storage, and dead organisms mean dead science. Even in physics, statics is separated from kinetics only for convenience in presentation, for equilibrium is but a special case of motion. Try to conceive of a separate science of chemical statics with a body of devotees who did not concern themselves with chemical reactions; and yet this would not be so preposterous as a science of organic equilibrium, when in organisms things are ever in a state of flux in adjustment to forces from within and without.

But, you will say, we have anatomists and physiologists, recognized in professorships in all universities, and we have societies for anatomy and for physiology. Surely there is a distinction to be recognized. Not long ago, one of our most eminent borderland scientists, who is commonly accounted a physiologist, made an interesting attempt to state this distinction and to set forth the true relations between anatomy and physiology. According to Loeb, anatomy should be presented in a physiological way, with full attention given to the working of the mechanisms, leaving to physiology the study of the dynamics of protoplasm or the constitution of living matter. There is much to be said in favor of this proposal. At least, anatomy could but profit by taking a physiological point of view, but it is not likely that either science will accept, in the future, even the slight limitation imposed by this scheme. Both will demand the whole field of the organic for study, each from its own point of view, but each, let us hope, giving more and more consideration to that of the other.

With our present store of descriptions, the crying need of anatomy is not to accumulate more but to demonstrate interdependencies of phenomena. The science was first investigated by means of the scalpel, later by means of the microtome. Now, let all instruments of experimentation, guided by a mental dissection or analysis, take their place alongside those time-honored tools. The best means of analysis or resolution of natural phenomena into simpler factors is experimentation. All the fields of investigation enumerated above are amenable to experimental study.

The plea for the general use of experimental methods in anatomy is not based upon the contention that a fact discovered by experiment is of more importance than one based upon observation. Nor is it meant that all experimental results are necessarily more cogent than purely observational ones. There are many footless uncritical experimental studies that lead nowhere, while carefully weighed observations may often lead to important generalizations. However this may be, phenomena as presented by nature without human interposition are usually enveloped in such a complexity of conditions that they cannot be readily resolved. Experimentation is simply a means for varying conditions purposefully, and is usually a far more effective one than nature unaided affords.

In the discussion which took place before this Association last year, I endeavored to show that it was necessary for us to free ourselves from the domination of the concept of the organism as a whole, and to give more attention to the factors of which it is composed. We must resolve the organism into elemental structures and processes, and make new combinations, to find out how the factors bear upon one another. The facts already brought to light by experimental embryology have amply demonstrated that our ideas of individuality must be profoundly modified, even with respect to the higher animals. The behavior of cells and small bits of tissue when removed from the influences of the whole organism has revealed a cellular autonomy beyond what even Schwann and Virchow conceived of. When pursued further, the experimental methods of study will enable us to state the facts of morphogenesis in simple terms of cellular activity, and we may hope to connect these with the results of microchemistry in localizing intracellular activities, and ultimately identify problems of structures and function with those of the protein molecule in its manifold physico-chemical relations.

The method alternative to experimentation (namely, that of comparison) has in anatomy yielded the one great generalization of homology or similiarity of plan and material in the structure of organisms, and comparative embryology has shown a unity in mode of origin. By revealing these similarities, the comparative method has rendered a great service in reducing the number of problems to be solved. But while it has enabled us to state problems with brevity and precision, it has almost totally failed to reveal causal relations. The dominant idea of comparative embryology, the recapitulation theory, has proved a woeful disappointment, and except in the form stated by von Baer, now stands, after half a century of sway, with less justification than ever. At best, it would be but a key to the deciphering of past history, and it would throw no light on the dynamics of development. It is, on the whole, extremely unlikely that the comparative method, as used in the past, will yield further generalizations, of first magnitude.

In correlating structural conditions with functional activity, the comparative method will be found much more effective. Here we have a double basis of comparison and a better chance of excluding unessential relations, even though conditions be complex. The method has yielded results in various fields of anatomy, but shows the most promise in neurology, thanks to the movement led by Edinger and so ably represented in this country by Herrick and Johnston. Even here, however, the simple method of comparing a series of normal structures and a series of normal activities, as observed in the intact organism, must give way to the anatomical and physiological experiment, if the analysis is to be complete and certain. Questions of functional adaptation are not matters for speculation and loose inference, but each case, to be credible, must be based upon sound experimental evidence. We learn, for instance, from the comparative anatomical study of the alimentary tract and by observing the feeding habits of animals, that there is some correlation between structure and function, but we are enabled to penetrate much more deeply into this relation by means of experiments, in which feeding of different kinds of food to one and the same species of organism, shows that the character of the function has a direct influence upon structure.

A new extension of the dual method of comparison which promises much, is in the field of cytology, where, amongst other achievements, we may look forward to the establishment of a definite relation between chromosomes and inheritance. Wilson has recorded and interpreted the results of many striking nature experiments in this field, but here again, actual experimentation is necessary to place beyond doubt the correlations indicated by plain observations. In the beautiful work of Boveri upon dispermic eggs, we have an example of what the experimental method can here accomplish.

In an interesting address "On the principle of comparison in physics"[3] Ernst Mach has pointed out how important a rôle analogy or comparison has played in this most exact of the sciences, citing, by way of example, the concept of potential, by which things so dissimilar as pressure, temperature and electromotive force are brought to show points of agreement. From this, however, we are far from being justified in assuming that comparison is a method of investigation sufficient in itself, for the use of analogy in physics has been of a different nature from its use in anatomy. In the former, comparisons have served as models to aid in forming concepts of more recondite phenomena, while in the latter, at least in so far as purely morphological comparisons are concerned, they have been used merely for purposes of classification or for mapping out supposed lines of descent.

Though urging the application of experimental methods to anatomical research, there has been no intention on my part to belittle the efforts of those who are treading other paths, nor any wish to dictate what others should be doing. Any problem that will arouse the interest and enthusiasm of the investigator is worth while, and everyone has the right to be free to follow his own bent. Investigation is less a matter of duty than of interest, even though, in the end, the value of a man's work be judged not so much by the enthusiasm it aroused in him, as by the magnitude of its influence upon later thought. He who is able to record the results of his investigations with accuracy and order is a master, and is entitled to the respect of his fellow workers, but this power of accurately recording observations, while fundamental to scientific progress, is not sufficient in itself, for it will not produce wide generalizations. All facts are not by any means of equal import, and in the process of making great discoveries, the power of discrimination, analysis, and vision of the general bearing of facts, will be found to overtop "the art of making durable trustworthy records of natural phenomena."[4]

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[3] Address delivered before the Gesellschaft deutscher Naturforscher und Aerzte, Vienna, 1894.

Whatever may be our judgment of the value of this or that particular method of investigation, we shall agree as to the necessity of maintaining contact between kindred subjects. As Mach expressed it in closing the address referred to above, "When the Congress of Natural Scientists shall meet a hundred years hence, we may expect they will represent a unity in a higher sense than is possible today, not in sentiment and aim alone, but in method also."

Meantime, anatomy, in order to maintain its influence upon scientific thought and bear a full share of the burden, must adapt the methods of other sciences to its ends. Its province, which is the solution of problems of animal form and structure in relation to function—problems as fundamental as any in biology—must be kept in constant communication with the province of physiology. With zoölogy, anatomy will in part share the field, but through close and inseparable relations with medicine it will have the advantage of being able to command always a certain human interest as well as a purely scientific one.

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[4] Charles Sedgwick Minot. The method of science. Vice-presidential address delivered before Section K of the A.A.A.S., at Minneapolis, 1910. Science, N.S., vol. 33, 1911.

CONCERNING THE MECHANISM AND DIRECTION OF EMBRYONIC FOLDINGS

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THREE FIGURES

There are three means by which a germ layer having the epithelial type of structure may expand (Minot): by the multiplication of cells; by the enlargement of cells; and by the flattening out of cells.

One or more of these methods, sometimes perhaps combined with other factors, are responsible for the expansion of any form of structure; they do not apply to the epithelial types of germ layers alone, but to all growing tissue. They are general. There is, however, an especially striking resemblance between the surface enlargement of a germ layer and that of the different kinds of epithelia.

The three modes of surface increase are not of the same importance in accomplishing the desired effect, the multiplication of cells is the most essential. There is also, it seems, a marked difference between 'multiplication of cells' and 'enlargement of cells' on the one hand and 'flattening out of cells' on the other. The first two might well be called an active expansion of the surface, while it seems appropriate to regard the third largely as a passive expansion. When, for instance, in the formation of the limb buds the mesoderm increases rapidly, the ectodermal epithelium, as far as the actual folding process is concerned, seems to take little *active* part in the expansion, but is pushed out and stretched in a more or less passive manner. Inciden-

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[1] This paper was in part worked out in the Histological Laboratory of the University of Munich. To Professor Mollier, head of the institution, my thanks are due for kindly furnishing me a place in his laboratory.

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tally, of course, the ectoderm will also continue to increase its surface by multiplication of cells, but this process is not responsible for the formation of the limb bud. In many instances, however, the epithelium increases its mass without being forced by the underlying tissue, and this is true in the formation of most of the important organs of the body. This *active* growth of the epithelium gives rise to the anlagen of the sense organs, lungs, liver, pronephros, mesonephros, and so forth.

Wiedersheim states for the formation of the lungs:

> An ihrer Bildung sind beide Blätter, Mesoderm und Entoderm, beteiligt: letzteres aber spielt beim Zustandekommen der gesamten Lungen-Architektur weitaus die Hauptrolle. Das *Entoderm* ist als das *treibende, formative* Princip zu betrachten. Es führt ein central fortschreitender Sprossungs- und Knospungs-Process des entodermalen Epithels zur Vervollkommnung der Lunge. Ontogenie und Phylogenie gehen parallel, und hier wie dort richtet sich die mesodermale Lungenanlage formell nach der entodermalen.

All the most important parts of the body arise from epithelial structures. Epithelium is the first structure to appear in development (blastula wall) and the first differentiation of this epithelium is most commonly gastrulation by invagination. This invagination is essentially the same process as that by which the anlagen of all the organs are derived from epithelium, even after an epithelium has become highly differentiated, and no matter from which germ layer it arose.

There begins a more *active* growth in special parts of an epithelium, which results in an invagination, if the growth occurs in a covering epithelium, while on the other hand it leads to an evagination in a lining epithelium. The ectoderm on the outside of the body invaginates to form the lens, ear, nose, ectodermal gill parts, mouth and so forth, yet as soon as it lines a cavity, it evaginates to form the optic stalk, infundibulum, and so forth. The entoderm does the same in forming the lungs, thyroid, liver and so forth. It thus seems to be the rule that *the epithelium as a result of active growth always bends towards the underlying mesoderm, that is, always away from a free space*, be it a cavity or the outside of the body.

A point of particular significance is the fact, that all of these foldings, either evaginations from the lining epithelia or invaginations from the covering epithelia, are always in the same direction as the original gastrular invagination. They are continuations in the original direction in which the archenteron began to fold, and all subsequent folds of the entoderm are still further inward, as liver, lungs, and so forth; while the ectoderm remaining outside always invaginates to form organs, just as the blastula invaginated to produce the gastrula.

The visible signs of a beginning embryonic fold are rather simple. First at the place where the fold will form an accelerated cell multiplication with an increase in the thickness of the epithelium is noticeable. This localized increase must necessarily lead to the formation of a fold, if the other parts of the epithelium or the underlying tissue do not allow of expansion. Yet there are other factors necessary always to turn these folds in the proper direction, that is, towards the underlying mesoderm or towards the space in which mesoderm will later develop. One of these factors might be found in the polarity of the epithelial cells. In any epithelial cell that part by which it is attached to the underlying tissue is more rigid than the free part. Nucleus, granules, and so forth, are usually located in the basal part of the cell. Even in the adult body many kinds of epithelial cells give evidence of polarity (Rabl), which means "a differentiation of protoplasm along the axis of the cell" (F. T. Lewis). The free and basal parts in themselves demonstrate the polarity of the epithelial cell. When cells have lost this specific polarity they no longer form epithelia but make up supporting and other kinds of structures. As an evidence of polarity cilia and flagella appear only on the free surface, while the nutrition of the cell takes place from the other pole.

When a part of an epithelium increases rapidly without being able to expand, the neighboring parts of this epithelium press on the increasing region and force it out of their level. It seems easier to compress the less stiff, free parts of the cells, than the stiffer, basal portions, which difference may cause the fold to start towards the underlying tissue. Hand in hand with the pressure from surrounding portions works that of the growing cells themselves. The increasing mass of the basal poles will tend to relieve the pressure in the direction of the arrows *a–a*, as indicated in figure 1.

In all active folding processes, therefore, the basal poles of the epithelial cells will form the apex of the fold. A purely mechanical principle could be held responsible for this effect.[2] However, it is impossible to say that nothing but mechanical factors are concerned in all the folding processes of the early embryo. I am simply attempting to explain the mechanical side of such processes; for one things is certain, that no folding, or any other process in development, could take place, if the proper physical conditions did not exist.

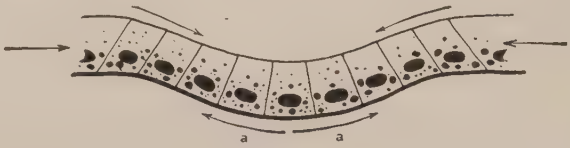

Figure 1

The same mechanism seems to play an important part even in the earliest folding process of the majority of organisms, gastrulation by invagination. A blastula can easily be compared to a single-layered epithelium enclosing a cavity, except that the basal parts of the cells form the lining of this cavity, while in all other cavities later than the blastocoel, the free poles of the cells line the lumen. On account of this condition the blastula is the only stage in which the active folding projects *into* the cavity, in all other cases it starts *away* from the cavity. The original direction of the fold in regard to the topography of the cell remains therefore unchanged.

The blastocoel is not a true cavity as is for instance, the neural tube, the cavity of the lungs, and so forth. It is wanting in some cases (epibolic gastrulation) and very much reduced in others. The first true cavity to appear is the gastrocoel, and the gastrocoel is formed in exactly the same manner as the neurocoel and other cavities.

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[2] The physicist is familiar with this phenomenon of bending. When two strips of paper of different thicknesses are pasted together and caused to bend either by warming or moistening them gradually, the thinner paper will always be on the concave side of the fold.

That the lining parts of the blastula cells are their basal poles, must be concluded from two factors. First, there are many blastulae, which possess cilia on their outer surface. Second, after gastrulation has taken place, the formerly outer poles become the lining surface of the digestive tract, while the formerly inner poles will be attached to the mesoderm as basal poles.

In gastrulation, therefore, the basal poles of the blastomeres form the apex of the folding in exactly the same manner as in every later folding process.

Through gastrulation a part of the blastula wall is brought into the blastocoel to form the entoderm. All later foldings of this entoderm go in the same direction as its first (gastrulation) fold; that is, always deeper inward and away from the cavity. The later folds of the entoderm are, therefore, only branches or ramifications of the first fold.

The ectodermal part of the blastula wall which does not invaginate retains its property to do so. All the later foldings of the ectoderm go in exactly the same direction as the first fold, they too are invaginations.

Ectoderm and entoderm, therefore, seem to be able to fold actively in one direction only, and the entoderm has retained this property from the time when it was still ectoderm.

The question now arises: why does the first folding process occur?

It seems that the above mentioned prerequisite of all folding processes, namely, the localized increase in mass or 'plate formation,' as it is called in the most typical cases, appears also in the invaginating gastrula as the preliminary stage of the folding.[3]

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[3] "The egg of Lineus lacteus undergoes equal cleavage, from which a regular blastula results. The latter loses its regular form before invagination begins. The cells at the vegetal pole increase considerably in size" (Metschnikoff); this is true of many other cases. "In Amphioxus the gastrulation begins by a flattening of the vegetative part of the egg" (Morgan and Hazen); and this also is true of other eggs.

If segmentation of the blastomeres should go on beyond the normal point without gastrulation the result would be a continual enlargement of the blastula, provided there was enough material for division present or available for assimilation from the surrounding medium. This, however, is not the normal course of events. After segmentation has been going on for some time the two poles of the blastula usually show differences. The cells at the vegetal pole are larger and higher than those at the animal pole. When the micromeres continue dividing they either press against the macromeres, and cause them to invaginate, or try to grow around them. The latter assumption was first made by Goette. Both processes will be furthered by the simultaneous expansion of the macromeres causing their basal poles to press in the same direction (figs. 2 and 3, in which the position of arrows indicates the direction of pressure).

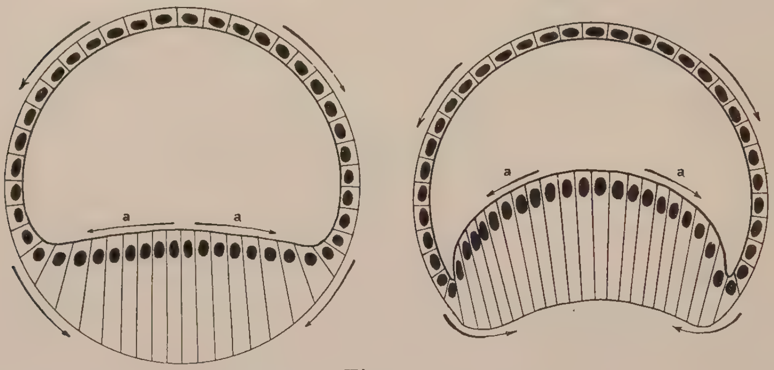

Figure 2

Epibolic gastrulation, as seen in Ctenophores and Annelids, seems to indicate that not only the growth of the macromeres, but also the rapid expansion of the micromeres, are forces concerned in gastrulation. The effect of the excessive growth of the ectoderm is seen most strikingly in the placula of Nematodes, and so forth, as described by Bütschli. Gastrulation in the Ascidiae is also to be kept in mind.

Since in the cases of gastrulation by typical invagination the non-invaginating cells are smaller than those which are to move into the blastocoel, the former are enabled to push over the latter thus assisting in the process leading to invagination. In Herbst's Lithium larvae all the blastomeres were swollen and showed a vacuolar appearance. Shortly before (exo-) gastrulation began, the entoderm cells lost their vacuoles and thus became *smaller* than the ectoderm cells. This is just the reverse of the normal happenings, and since gastrulation took place in the direction opposite to the normal, the surmise is warranted that the size of the blastomeres plays an important part in gastrulation. In the Lithium larvae the larger 'micromeres' were not able to push over the smaller 'macromeres.' The larger cells, on the other hand, did not start to invaginate because the arch formed by them was so much larger than that of the smaller cells (cf. p. 418).

There are, however, a few cases on record in which the cells at the vegetal pole are the smaller ones, yet apparently they invaginate. Most of these cases are met with in the Scyphomedusae. "In spite of the numerous reports on this subject, many of which are contradictory, the process of germ layer formation in this group of animals is not yet perfectly understood" (Korschelt and Heider). Conklin describes gastrulation by unipolar immigration or invagination in different eggs of the same animal, Linerges mercurius, and states "that in other genera of Scyphomedusae all forms of gastrulation may occur." Hyde and Smith make similar statements for Aurelia flavidula and marginalis, and many other authors claim the same for the rest of the Scyphomedusae. Thus Korschelt and Heider were, recently (1910), forced to state "that at present it is impossible to get a clear picture of the formation of the entoderm in this group of animals. Later investigations will have to show, whether or not one or more of the important stages of development have escaped the observations of the authors, (Hyde and Smith)."

One fact seems certain, that the formation of entoderm by true invagination is not the typical case in the Scyphomedusae, therefore, other factors differing from the one discussed here may work in this special mode of gastrulation.

There is, however, a point of interest in this somewhat indeterminate type of gastrulation as compared with the typical gastrulation by invagination. In the latter type the row of micromeres is always longer than that of the macromeres, while in the Scyphomedusae the row of non-invaginating macromeres is longer than that of the cells which are to move towards the blastocoel. There may be some mechanical force connected with this phenomenon. Rhumbler has compared the blastula with a bow, the ectodermal cells forming the arch, the entodermal the cord. In all blastulae the ectodermal 'arch' is longer than the entodermal 'cord,' even if the cells at the vegetal pole are smaller than those on the other. The arch then, according to Rhumbler, would always enact some influence on the cord, and vice versa.

Cases have been described in which there was apparently no difference between the two poles of the blastula. In Terebratulina septentrionalis Conklin "finds it quite impossible to distinguish any difference between the cells which invaginate and those which do not, until after the gastrulation is well advanced. Gastrulation occurs by typical invagination and at the time when the infolding begins, there is no difference in the cells at the two poles."

In such cases, invagination might start at any place since the inner poles of the cells are everywhere under less pressure than the outer poles. Yet the region, where it occurs, must be somewhat different from the neighboring parts, although this difference may not be discernible.

That there are differences in the blastomeres, although not always in size, is stated by Metschnikoff in a description of Aeginopsis: "Although in the 16-cell stage the blastomeres do not differ in size, they show other differences. Some cells reach the surface of the blastula with a large part of their body, others only with a small portion. The latter cells, irregularly distributed over the surface of the embryo, later on get into the blastocoel . . . . ." This case seems to indicate that it is simply pressure which pushes some blastomeres into the blastocoel, because before these cells start to migrate they are already somewhat pressed away from the surface.

Roux and Rhumbler were the first to point to the different sizes of the blastomeres as being influential in gastrulation. Rhumbler, however, believes that chemotaxis alone is the inducing factor of gastrulation, while mechanical forces serve merely to assist the process after it has once begun. Yet there are some reasons, at least, to think that mechanical agents alone might force the entodermal cells towards the blastocoel.

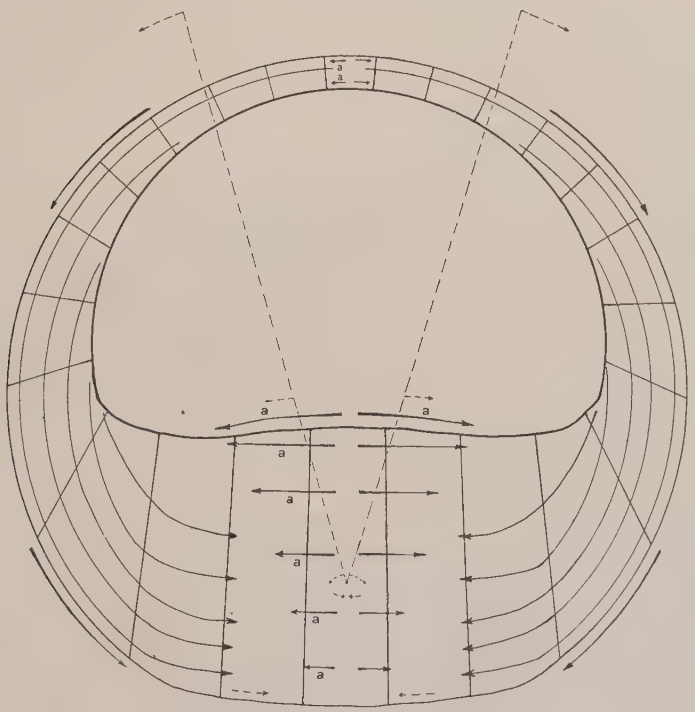

Figure 3

Figure 3, in which the direction of pressure is indicated by the arrows, will show, how mechanical forces might play a very important part in invagination. The compression from the side of the ectoderm will be the greater, the nearer to the periphery the compressed region lies. On the other hand, the tendency to expand will be greatest near the basal poles, since in this region lie more of the formed parts of the cells (yolk granules, etc.).

During segmentation of yolk-laden eggs the yolk becomes located more and more towards the inner parts of the blastomeres. "And it is clear," Assheton says, "that the distribution and quantity of yolk relative to the upper and lower poles is an all important factor in the process of invagination." The relative position of the nuclei of the blastomeres varies in different species. In the literature there are hardly two statements which agree in this respect, while most of the illustrations of gastrulation are so diagrammatic as not to allow of interpretations. However, the location of the nucleus, as a centre of force, may also play an important part in gastrulation, as Assheton recently tried to point out (cf. Assheton).

With each cell division the ectodermal pressure becomes greater. In consequence of this more and more of the formed and liquid content of the entodermal cells will be pressed to their inner poles, which in turn will create a greater tendency on the part of this region to expand, and finally both forces will produce the invagination.

If, in addition the cells take up material from the blastocoel, as Rhumbler states, the increasing pressure on the basal poles will still further this effect.

The diagram 3 also shows, why the micromeres do not invaginate. In them, of course, the pressure differences between basal and peripheral poles are much smaller than in the macromeres.

In Roux's ('97) gastrulation experiments with oil drops, chemotaxis certainly played no part in forcing the larger oil drop into the 'segmentation cavity' (Roux's fig. 21). It was simply pushed in by the pressure of the smaller oil drops.

Rhumbler claims that this phenomenon cannot be compared with actual gastrulation, since dead cells like the oil drops would be forced from the region of high to that of low pressure, while in a row of living cells they all would flatten out to a mere film, if necessary.

This reasoning would be true, if the pressure were on both sides ideally equal along the entire height of the cells, but such is not the case, as the diagram shows. When a piece of skin is pressed between two fingers the cells do not flatten out, but are simply forced from the region of high to that of low pressure. There is, therefore, a certain resemblance between Roux's oil drop experiments and the natural process of pressing the entodermal cells into the blastocoel. The oil drop, however, loses its connection with the neighboring drops. The invaginating cells would do the same, and often do, but for the reason that the blastomeres have a strong hold on one another (Cytarme), while the oil globules have not. In addition, the number of cells under pressure is not limited, those cells which have not yet invaginated are also under pressure and are thus forced to follow the invaginating ones.

Rhumbler's assumption that chemotaxis plays an important part in gastrulation is no doubt partially correct. The mechanical influences, however, are also of importance. If migration of cells caused by chemotaxis was the only factor accomplishing gastrulation, it would be difficult to understand why actively migrating cells keep up a definite epithelial arrangement and do not become disarranged. There is attraction between the cells (Zur Strassen), and there can scarcely be attraction and active migration in equilibrium at a given time.

Active migration of the future entodermal cells might perhaps explain gastrulation by polar and multipolar immigration, the latter being a rather rare type of gastrulation. Yet mechanical influences pushing some cells out of the level of the others might explain it as well (Aeginopsis).

Multipolar immigration is just the fact that seems to argue most against the theory that chemotactic influences are the main forces concerned in gastrulation. Yet many biologists regard these cases as the best proof of chemotaxis. Metschnikoff and others have assumed that some blastomeres actively migrate into the blastocoel on account of certain ('phagocytic') properties they possess and because they are thus destined later on to form entoderm. These cells are distributed irregularly over the blastula surface. Many experiments and observations, however, have shown that in blastulae with a 'determinate cleavage' the cells that are destined to form special parts of the embryo lie in definite groups. The cell groups come, of course, from certain early blastomeres which have transmitted to them their specific potential factors (cell lineage). Therefore, if the cells, which in multipolar immigration move into the blastocoel, would immigrate only for the one reason that they have specific qualities which the remaining cells do not possess, or because they are 'destined' to form entoderm, one should expect to find them grouped in a certain zone of the blastula, as they are descendants of one or more cells of the early cleavage stages. They are, however, irregularly distributed over the surface of the blastula which makes it seem improbable that they possess qualities differing from those of the rest of the cells. They are more probably forced into the blastocoel by outside conditions, and later on, because they are lying within the blastocoel, they undergo such histological differentiation as to make them fit to form entoderm.

It is obvious that chemotaxis with consequent active migration is not always necessary to induce gastrulation. The epibolic type of gastrulation, for instance, cannot be explained by chemotactic migration, since here the macromeres lie within the segmentation cavity, while the micromeres tend to grow over them. If chemotropism plays the important part in invagination as is generally supposed, it is probably only one of the factors creating the proper pressure conditions that are necessary for invagination. It seems, however, that the pressure in the blastula wall alone would suffice to start the invagination, since the inner poles of the blastomeres are always under lower pressure than the outer ones.

By warming sea water to 30°C., Driesch could force Sphaerechinus blastulae to undergo exo-gastrulation, a phenomenon which shows that gastrulation is dependent on physical factors. Driesch states "that the growth of the blastula wall is the vital, fundamental process; the direction towards which the growth proceeds is determined by the surroundings."

In another series of experiments Driesch separated the micromeres from the macromeres of Echinus blastulae by shaking. In both groups the respective cells arranged themselves as blastulae, and in both types of blastulae, after cell division had proceeded for some time, invagination took place. Driesch therefore says that "any cell of the blastula wall may give start to the formation of entoderm." The surmise is warranted that, at least in the blastulae composed only of micromeres which normally had no chemotactic tendency to immigrate, pressure was the chief factor in inducing gastrulation.

It is not the purpose of the foregoing discussion to show that mechanical forces are the only factors concerned in gastrulation by invagination, *but rather to emphasize the great morphological similarity shown by all the folding and budding processes in development.* Since there is such a striking morphological resemblance between gastrulation and the anlage of most of the organs, one is justified in looking for similar producing forces.

In summarizing the main points of the discussion it may be stated:

1. One of the forces causing the fold always to turn in the proper direction is very likely to be found in the pressure differences based on the polarity of the epithelial cell.
2. The thickening of the region, which starts to fold, is a preliminary stage in every folding process. Its consequences are: (a) the polar differences in the epithelial cells become emphasized or exaggerated, since the cells become much higher than the rest of the epithelium; and (b) the rapid cell multiplication calls forth the necessary pressure from the neighboring regions to cause the compressed cells to leave the level of the epithelium.

The preliminary thickening of the region prior to folding seems to be universal, a fact that suggests its great importance. This has been observed by many morphologists, yet it has never received the proper comment from a mechanical standpoint.

A few of the instances in which it has been stated morphologically, may be mentioned here.

In man the epithelium of the Wolffian duct increases, according to His, to double the thickness at the place from which the ureter will bud off. Similar observations have been made by Riede in the sheep, by Schreiner in the rabbit, by Sedgwick and others in birds.

H. Rabl studied the development of the Müllerian duct in Salamandra maculosa and found that an area of cylindrical cells appears in the flattened mesothelium, before the invagination for the Müllerian duct takes place. Brauer describes a similar localized increase in height in the peritoneal epithelium of Hypogeophis which leads to the formation of a fold, the forerunner of the Müllerian duct. Braun and Mihalkowicz describe the same process in reptiles. Keibel and Abraham state that in birds the low mesothelium first becomes cylindrical, then increases the number of layers and finally invaginates. In mammals the same process has been seen by many observers.

In Amphioxus, according to Zarnik, the gonads are laid down as foldings following very noticeable elongation of the epithelial cells.

Maurer describes, in Bufo vulgaris, that part of the epithelium, which by folding is to form the post-branchial body, "as different from the rest of the gill cleft epithelium. It contains very high cylindrical cells and is easily distinguishable from the neighboring region."

One or the other of the principles outlined above seems to be involved in every fold leading to the anlage of an organ.[4] None, however, holds good for the foldings of the fetal amniotic membranes. In the formation of the amnion the basal poles of the cells—'basal' in view of the ectoderm from which the amnion arises—form the apex of the fold.

[4] One exception is the formation of the optic cup. Here the neuro-ectoderm, pushing off from the central canal as optic vesicles, invaginates to form the cup in such a fashion that the *free* poles, those toward the lumen of the nerve tube, form the *apex* of the fold. No possible explanation can be found for this deviation from the usual course. However, one fact is worth considering. Although in the formed retina the region towards the vitreous humor is still the basal one histologically, yet functionally the region towards the pigment (rods and cones) is the more active one. It seems as if a change in the functional polarity of the retina had taken place, as compared with that of the original neuro-ectoderm. Furthermore in the formation of the optic cup the invaginating part, the latter nervous layer of the retina, is many times higher than the outer pigment layer; a difference in thickness of the two layers so characteristic in invagination.

Yet this folding process is a very different mechanism from the anlage of an organ. There is no localized thickening or plate-formation, but the multiplication of cells is uniform all over the sheet, so that the fold is not forced to start in a certain direction. Besides, the cells are so flat that there is hardly a difference between their two poles, and both poles are free. Furthermore, the somatic layer of mesoderm pushes or grows against the ectoderm in a way somewhat similar to the outpushing of the limb buds. For these reasons this folding may be considered as of the passive type. The allantois, on the other hand, arises from the hind gut in a manner entirely in accord with the principles of foldings I have set forth.

So far only active foldings of a germ layer or epithelium have been discussed. In passive foldings a germ layer can expand chiefly by a flattening out of its cells (third mode).

In the formation of the limb-bud, as mentioned in the introduction, the expansion of the mesodermal structures seems to be the main factor causing the ectoderm to fold out with the free poles of its cells at the apex of the fold.

In Sphaerechinus larvae which were raised in sea water and K salts, Herbst observed a retardation in the formation of the skeleton and arms of the pluteus. He remarks "that the outgrowth of the arms is caused by the stimulus created by the growing skeletal parts on the body wall."

Mollier observed in Lacerta that in the formation of the limb buds the mesoderm is the first tissue to increase in thickness, Bardeen and Lewis describe a similar process in man. Thus the growing mesoderm starts the formation of the limb-bud, secondarily the ectoderm increases somewhat in thickness.

In fishes the formation of the extremities is complicated. First an increase in the thickness of the somatopleura by rapid cell division is noticeable, as shown by Boyer for the teleosts, K. Rabl and Mollier for the selachii (first stage). After this mesodermal ridge has reached a certain thickness the covering ectoderm begins to increase its mass (second stage). Later the ectoderm begins to rise up in form of a longitudinal fold (third stage), into which the mesoderm rapidly expands (fourth stage). The interval between the mesodermal thickening and the rising of the ectoderm is different in different animals. In Ceratodus, for instance, the independent folding of the ectoderm is missing entirely, in Torpedo it takes place along with the mesodermal increase (Ziegler).

Stage 3 of the above quoted mode of limb budding, namely, the independent rising of the ectoderm, is apparently not in accordance with the mechanism this paper is supposed to point out. The independently folding epithelium should fold towards the mesoderm. It does just the opposite. Three reasons seem to be worth considering that may explain this apparent exception to the rule:

1. It has been proven that the mesenchym starts the budding; that is to say, it causes or stimulates the ectoderm to begin to fold away from the underlying tissue.

2. The folding of the ectoderm, does not seem to be absolutely independent of the mesenchym; for example, the absence of such folding in some species and its coincidence with the mesenchymal thickening in others. It seems much more likely that the four stages of budding are not as strictly separated from one another as it appears from the description, but do somewhat overlap as in Torpedo.

3. If the ectoderm really does fold independently, than in this special instance it cannot possibly turn towards the underlying tissue, since the latter expands actively towards the ectoderm.

There can be little, if any, doubt that in the formation of the limb buds the thickening of the ectoderm is merely a secondary process. Several authors emphasize this point. Boyer, for instance, says: "I am convinced from my own observations upon shark embryos that in the latter, as in Fundulus, the earliest step in the development of the pectoral fin is not a modification of the ectoderm, as supposed by Balfour and accepted by Dohrn, but that the beginning must be referred to the proliferation of the mesoderm in the somatopleure, as I have already pointed out for Fundulus." Mollier states: "So much I am able to say, that in Torpedo as well as in Pristiurus, and Mustelus the thickening of the somatopleure was noticeable, while the ectodermal cells did not show the slightest increase in height." Also in the limb formation in Lacerta muralis Mollier speaks of a mesodermal with following ectodermal thickening. So Braus is correct in saying "that the ectodermal ridge is the visible sign of the developmental processes taking place in the underlying mesoderm."

That the ectodermal thickening is merely a reaction to the mesodermal thickening also seems obvious from observations made on Torpedo by K. Rabl. The thickening of the mesoderm with following growth of the ectoderm takes place independently in fore and hind extremities. Later a connection between the two separate anlagen is established, the mesoderm increasing first and being followed by the thickening of the ectoderm. This secondary stage Balfour mistook for the primary one and made it the basis for his "lateral fold hypothesis." The connecting portion later disappears, and this shows that the ectoderm increases, as soon as the mesoderm thickens although no formation of an extremity takes place afterwards.

Though it cannot be proven definitely, it may be strongly suggested that the same mechanism that is involved in the formation of the limbs is manifest in the outpushing of the villi in the intestines, chorion, gill filaments, choroid plexus, and so forth. In all these cases the mesoderm increases on account of the rapidly growing blood vessels, while simultaneously the ecto- or entoderm, either reacting to the stimulus from the mesoderm or more likely independently, increases rapidly by cell multiplication, so that both processes practically go hand in hand. Therefore, since the epithelium in these cases cannot fold or bud towards the supporting tissue, it must do so in the opposite direction.

Maurer believes, that in the formation of the intestinal mucous membrane the actively growing mesoderm undoubtedly plays an important part, yet the investigations so far performed have thrown no definite light on the specific mechanism. Indeed, it will readily be seen that the reports by different authors on the formation of intestinal villi are very contradictory.

Gianelli claims that in the reptiles first an increase in the number of epithelial cells takes place, which leads to the formation of a fold, into which connective tissue grows secondarily.

In birds Seyfert finds that the connective tissue gives the impulse to the formation of villi, starting cone-like elevations which push the epithelium into the lumen of the gut. In man and mammals, as Brand and Barth report, epithelium and connective tissue increase simultaneously. Voigt studied this process especially in the pig. Yet Patzelt, on the other hand, claims that the villi are started as epithelial elevations while the connective tissue plays merely a secondary rôle.

More conformity seems to underlie the different reports that have been made on the formation of intestinal glands, Lieberkühn's crypts, and so forth. All authors agree that the glands start as foldings or sproutings of the epithelium towards the mesoderm. This is in accordance with my view that an independent growth of the epithelium will fold towards the underlying tissue. Some discrepancies, however, exist as regards the early anlage of the glands. Oppel speaks of the formation of solid epithelial processes, Voigt, however, observes foldings of the epithelium. Seyfert, in birds, and Gianelli, in reptiles, describe solid, while Barth and Brand, in mammals, speak of hollow outpushings of the epithelium.

In every case, whether a solid or a hollow folding of the epithelium is formed, it always starts towards the mesoderm, and leads to the formation of a gland or crypt, while on the other hand, when the mesoderm grows rapidly a villus or intestinal fold is formed. Thus it seems as if the two opposing theories, Edinger's and Oppel's, may both be accepted as correct in part. Edinger believes in the growth of the mesoderm as initiative and secondarily the entoderm folds leading to the different formations in the intestinal tract, while Oppel holds the entoderm alone responsible. Edinger's view seems to be correct as regards the folds and villi, and Oppel's as regards the glands.

The interaction between the ectoderm and mesoderm is very strikingly seen in the formation of the enamel organ and dental papillae of the developing tooth. The ectoderm at first thickens and starts towards the mesoderm to form the enamel organ and later a cone of mesoderm grows up to form the dental papilla and pushes the ectoderm again towards the outside. Here then both processes are illustrated, the active folding of the ectoderm towards the mesoderm and the passively outpushed ectoderm by the growing mesoderm below. The developing hair undergoes a similar process.

SUMMARY

From all histological observations that have been made on folding germ and epithelial layers, and from a mechanical interpretation of these structures, the following conclusions may be reached:

1. In all folding processes in which an epithelium takes an *active part*, the basal poles of its cells form the apex of the fold.
2. All folding processes in which the free poles of the epithelial cells form the apex, are *passive* folds, caused by the rapid growth of the underlying tissue.

BIBLIOGRAPHY

Abraham, K. 1901 Beiträge zur Entwicklungsgeschichte des Wellensittichs. Anat. Hefte, p. 591.

Assheton, R. 1910 The geometrical relation of the nuclei in an invaginating gastrula (e.g., Amphioxus) considered in connection with cell rhythm, and Driesch's conception of entelechy. Arch. f. Entw., Bd. 24, p. 46.

Bardeen, C. R. and Lewis, W. H. 1901 Development of the limbs, bodywall and back in man. Amer. Jour. Anat., vol. 1.

Boyer, 1892 The mesoderm in teleosts, especially its share in the formation of the pectoral fin. Bull. Mus. Comp. Zool., Harvard, 23.

Brauer, A. 1902 Beiträge zur Kenntnis der Entwicklung und Anatomie der Exkretionsorgane. Zool. Jahrb., An. Abt., Bd. 16, p. 1.

Braun, M. 1878 Das Urogenitalsystem der einheimischen Reptilien, entwicklungsgeschichtlich und anatomisch bearbeitet. Arbeit. d. zool. zoot. Inst., Würzburg, Bd. 4.

Braus, H. 1906 Die Entwicklung der Form der Extremitäten und des Extremitätenskeletts. Hertwig, Handb. d. Entwickl., Bd. 3, p. 2.

Bütschli, O. 1883 Bemerkungen zur Gastraeatheorie. Morphol. Jahrb., Bd. 9, p. 415.

Cerfontaine, P. 1906 Recherches sur le développement de l'Amphioxus. Arch. Biol., tome 22.

Conklin, E. G. 1909 The habits and early development of Linerges mercurius. Publ. Carnegie Inst., Washington, 103.

1892 The embryology of a Brachiopod. Proc. Amer. Phil. Soc., vol. 41.

Driesch, H. 1893 Exogastrula und Anenteria. Mitteil. Zool. Stat. Neapel, Bd. 11, p. 221.

1894 Analytische Theorie der organischen Entwicklung. Leipzig.

Gianelli, Struttura ed istogenesi dell' intestino digestive nella Seps chalcides. Atti R. Ac. Fisiocritici, Siena, ser. 4, tomo 12, p. 11.

Goette, A. 1884–86 Abhandlungen zur Entwicklungsgeschichte der Thiere, Heft 2–3, Hamburg–Leipzig.

Herbst, C. 1896 Über das Ineinandergreifen von normaler Gastrulation und Lithium-Entwicklung. Arch. f. Entw. Mech., Bd. 2, p. 455.

Hertwig, O. u. R. 1879–83 Studien zur Blättertheorie. Heft 1–5, Jena.

His, W. 1868 Untersuchungen über die erste Anlage des Wirbeltierleibes. Leipzig.

1874 Unsere Körperform und das physiologische Problem ihrer Entstehung. Leipzig.

1894 Über mechanische Grundvorgänge tierischer Formenbildung. Arch. f. Anat. u. Physiol. Anat. Abt.

Hyde, J. H. 1894 Entwicklungsgeschichte einiger Scyphomedusen. Ztschr. wiss. Zool., Bd. 58.

Keibel, F., u. Abraham, K. 1900 Normentafeln zur Entwicklungsgeschichte des Huhnes. Jena.

Lewis, W. H. 1902 The development of the arm in man. Am. Jour. Anat. vol. 1.

Maurer, F. 1888 Schilddrüse, Thymus und Kiemenreste bei Amphibien. Morphol. Jahrb., Bd. 13.

1906 Die Enwicklung des Darmsystems. Hertwig, Handb. d. Entwickl., Bd. 2, p. 1.

Mayer, P. 1886 Die unpaaren Flossen der Selachier. Mitteil. Zool. Stat. Neapel.

Metschnikoff, E. 1882 Über die Gastrula einiger Metazoen. Ztschr. wiss. Zool., Bd. 37.

von Mihalkowicz, 1885 Untersuchungen über die Entwicklung des Harn und Geschlechtsapparates der Amnioten. Intern. Monatsschr. f. Anat. u. Physiol., Bd. 2.

MINOT, C. S. 1909 Laboratory text-book of embryology; 2nd edition.

MOLLIER, S. 1895 Die paarigen Extremitäten der Wirbeltiere. Anat. Hefte, Bd. 5.

MORGAN, T. H., AND HAZEN, A. H. 1900 The gastrulation of Amphioxus. Jour. Morph., vol. 16, p. 569.

OPPEL, A. 1896, 1900 Verdauungskannal. Merkel-Bonnet, Erg. d. Entwickl.

PATZELT, 1882 Über die Entwicklung der Dickdarmschleimhaut. Sitzber. Ak. Wiss. Wien.

RABL, C. 1889 Über die Principien der Histologie. Verh. Anat. Ges., Berlin, Bd. 3, p. 39.

1893 Theorie des Mesoderms. Morph. Jahrb., Bd. 29.

RABL, H. 1904 Über die Entwicklung des Tubentrichters und seine Beziehung zum Bauchfell bei Salamandra maculosa. Arch. f. Mikr. Anat., Bd. 64.

RAUBER, 1880 Formbildung und Cellularmechanik. Morph. Jahrb., Bd. 6.

RIEDE, 1887 Untersuchungen zur Entwicklung der bleibenden Niere. Inaug. Diss. München.

ROUX, W. 1896 Über die Bedeutung 'geringer' Verschiedenheiten der relativen Grösse der Furchungszellen für den Charakter des Furchungsschemas nebst Erörterungen über die nächsten Ursachen der Anordnung und Gestalt der ersten Furchungszellen. Arch. f. Entw. Mech., Bd. 4, p. 1.

RHUMBLER, L. 1902 Zur Mechanik des Gastrulationsvorganges, insbesondere der Invagination. Arch. f. Entw. Mech., Bd. 14, p. 401.

SCHREINER, K. E. 1902 Über die Entwicklung der Amniotenniere. Ztschr. wiss. Zool., Bd. 71, p. 1.

SEDGWICK, A. 1880 Development of the kidney in the relation with the Wolffian body in chick. Quart. J. Micr. Sc., vol. 20, p. 146.

SEYFERT, 1897 Beiträge zur mikroskopischen Anatomie und zur Entwicklungsgeschichte der blinden Anhänge des Darmkanals bei Kaninchen, Taube und Sperling. Inaug. Diss., Leipzig.

SMITH, F. 1891 The gastrulation of Aurelia flavidula. Bull. Mus., Harvard, vol. 22.

STOCKARD, C. R. 1907 The embryonic history of the lens in Bdellostoma Stouti in relation to recent experiments. Am. Jour. Anat., vol. 6, p. 511.

1910 The independent origin and development of the crystalline lens. Am. Jour. Anat., vol. 10, p. 393.

VOIGT, J. 1898 Zur Entwicklung der Darmschleimhaut. Nachr. Ges. Wiss., Göttingen, mat.-naturw. Kl., Bd. 4, p. 416.

ZARNIK, B. 1904 Über die Geschlechtsorgane des Amphioxus. Zool. Jahrb., An. Abt., Bd. 21, p. 253.

ZIEGLER, H. E. 1888 Der Ursprung der mesenchymatischen Gewebe bei den Selachiern. Arch. f. mikr. Anat., Bd. 32.

THE RATE OF GROWTH OF THE ALBINO RAT[1]

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EIGHT CHARTS

Growth is commonly measured by the successive changes in stature or in weight, or by the combination of both of these measurements. Although each of these methods shows accurately how the animal is growing, none of them is capable of furnishing a direct measure of the rate of growth. This, as Minot[2] has pointed out, may be measured by the percentage increase, based on the initial weight, during a definite length of time, not by the absolute increments during the same length of time. Therefore an animal of 50 grams initial weight which gains 5 grams in a given time, has a much higher rate of growth than the animal of 150 grams which gains 10 grams in the same length of time. Minot[3] has published curves showing the rate of growth for man, guinea-pigs, rabbits, and chickens, which agree in exhibiting during the first few days of life a very large daily percentage increment, which rapidly falls toward the zero line. These curves indicate that the rate of growth is a variable function of age, and that the period of life which is ordinarily associated with the most rapid growth is, in reality, the period of most rapid decline in the power of growth.

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[1] The expenses of this investigation were shared by the Connecticut Agricultural Experiment Station and the Carnegie Institution of Washington, D. C., in connection with the nutrition investigations of Dr. Osborne and Dr. Mendel.

[2] Minot, Senescence and rejuvenation. Journ. of Physiol., vol. 12, pp. 97–153, 1891.

[3] Minot, The problem of age, growth and death. 1908. Chap. 3.

This view that the rate of growth is dependent upon age is supported by Pfaundler.[4] In a set of curves which he gives of two infants, one of which was prematurely born, the rate of growth of the latter was much higher than that of the normal infant with which it was compared, although its actual increase in weight during that time was much less. If, however, the curve is shoved over three months, so as to make it agree with the age of the normal infant, counting from the time of conception ('Konzeptionsalter' as opposed to 'Geburtsalter') the two curves are almost identical. Since the intra-uterine rate of growth is much higher than the extra-uterine, the abnormally high rate of growth manifested by this infant at first was due to the carrying over of the higher intra-uterine rate of growth, corresponding to a greater 'Lebenspotential' or 'Lebenskraft' than is normal at birth. That the cessation of growth is due to age is a necessary corollary to these facts.

Davenport,[5] on the other hand, does not quite agree with this theory. He says "the reason why the animal ceases at length to grow is—not because there is a necessary limit to growth force at a certain distance from impregnation but because it is in the nature of the species that the individual should cease to grow at this point. The indefinite growth of this part, the limited growth of that, are as much group characters as any structural quality."

The present paper aims to give briefly some data regarding the rate of growth of the albino rat. The method used is essentially that employed by Minot in his study of guinea-pigs. The average growth curve for the albino rat was determined from the actual curves of a large number of animals, and from this was calculated the daily percentage increments for ten-day periods. Rats raised under identical external conditions exhibit wide variations in weight at any given age, so that it is difficult to get a good average; but as the majority of these animals tended to

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[4] Pfaundler, Ueber die Behandlung angeborener Lebensschwäche. Münch Med. Wchs., Bd. 54, p. 1417, 1907 (July 16).

[5] Davenport, Experimental morphology. Part II, Chap. 10, 1899.

In all the charts the abscissae represent days and the ordinates percentage increments. In charts 1, 2, 3, 4 and 5 the initial percentage is calculated from the weight at birth as given by Donaldson: (A comparison of the white rat with man in respect to the growth of the entire body. Boas Memorial Volume, 1906).

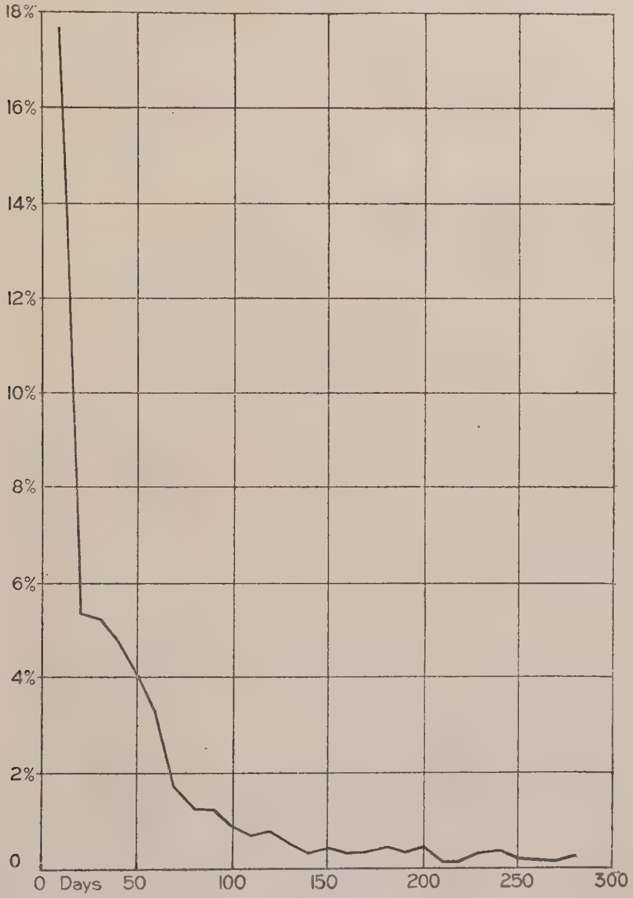


Chart 1 Average rate of growth for the male albino rat

group themselves about this average curve, it is probably sufficiently accurate for the purpose.

Charts 1 and 2 show the average rate of growth for male and female albino rats. These are of the same general form as those of Minot's for other animals. The very high initial values, 17.7

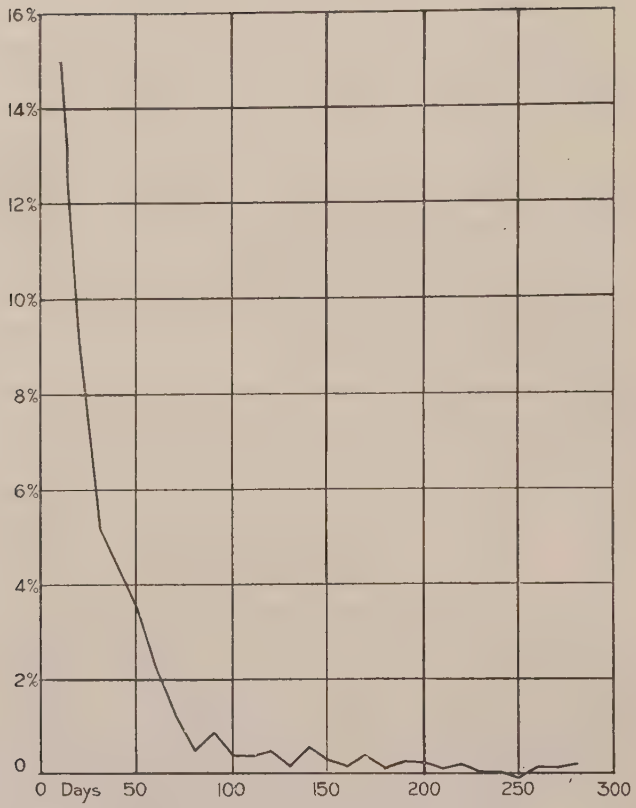


Chart 2 Average rate of growth for the female albino rat

per cent for the males, and 15.0 per cent for the females, are due to the fact that rats, like rabbits, are born in a very immature state; blind, without teeth or hair, and incapable of any muscular coordination. In fact, a rat three weeks old is no more mature than a guinea-pig at birth, from which time on, the curves for the two animals show more or less agreement. The irregularities in the latter part of the curves are probably caused by an insufficient number of observations.

Chart 3 shows the rate of growth of a very large rat, whose curve of growth varied greatly from the average, and chart 4 shows that of a very small rat. These curves have the same gen-

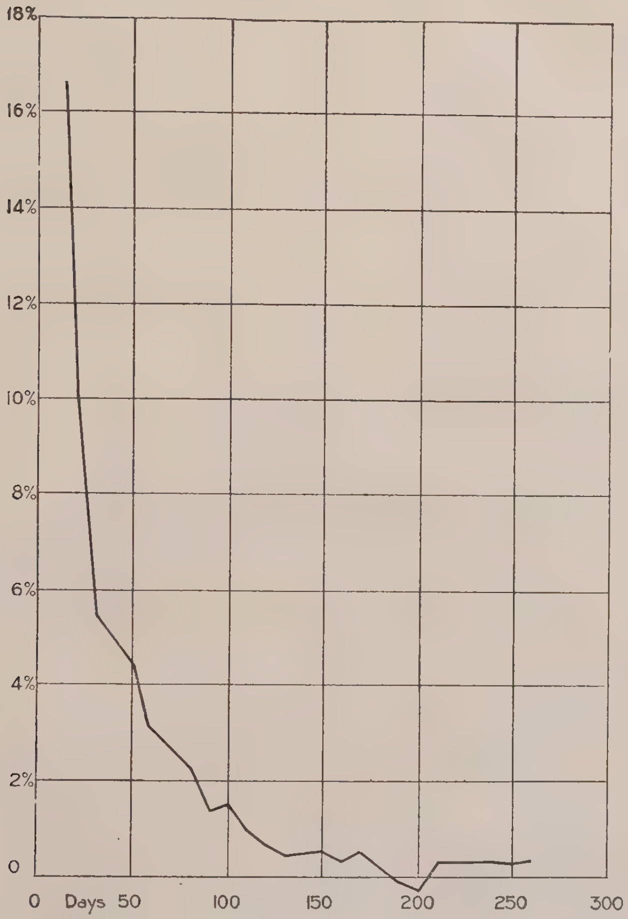


Chart 3 Rate of growth of an unusually *large* male rat

eral features as those for the normal, varying only in the rapidity of the decline.

Charts 5 and 6 show the rate of growth of two rats which were stunted from the time of weaning until they were 89 and 314 days old respectively. At this time the food was changed, and although both of them had reached an age at which a normal animal grows very slowly, or not at all, they immediately began growing at a rate normal for their size, or even at a slightly higher

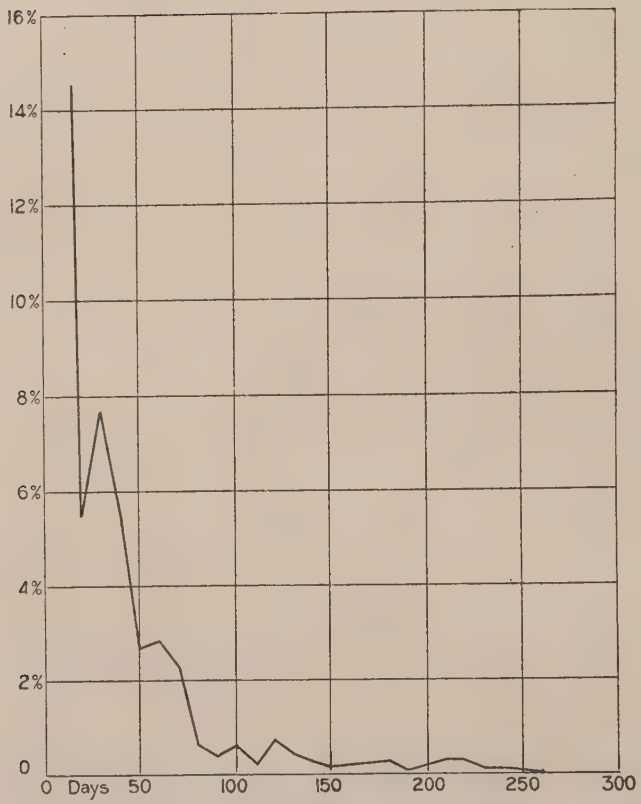
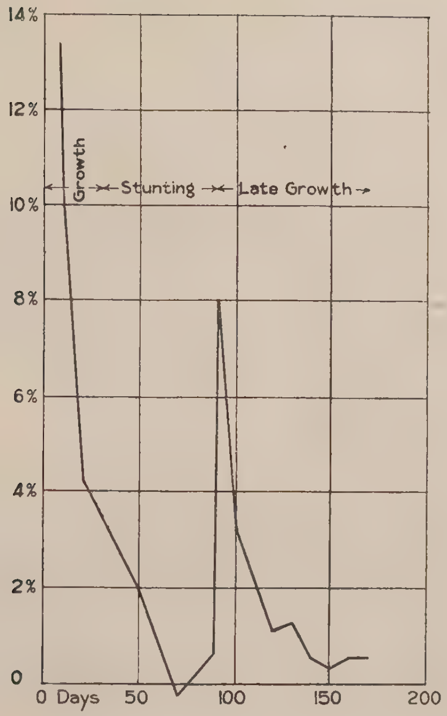


Chart 4 Rate of growth of an unusually *small* male rat

one, apparently in an endeavor to reach the size which they would have attained had they not been subjected to a preliminary period of stunting.

Charts 7 and 8 show interesting curves of repair, followed by late growth. These animals grew normally for a time, then declined seriously and were brought back to a weight normal for their age, at a rate somewhat above the normal.

These experiments prove conclusively that the power of growth is not lost so early in life as one would be led to suppose from a study of the curves of normal animals only. Whether or not it is ever lost is a question which can only be answered by ex-



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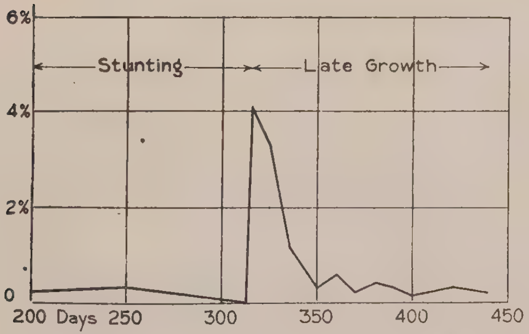

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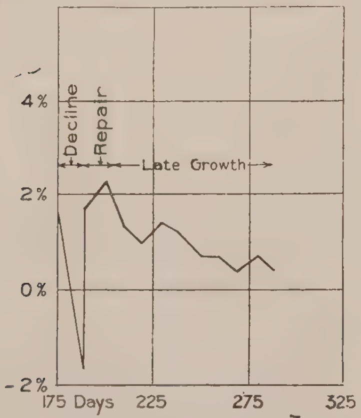
Chart 5 Shows the rate of growth of a female rat whose growth period was interrupted by a period of stunting lasting from 30 to 89 days of age. When the rat resumed growing, at an age when growth is normally very slow, it weighed 37 grams, the average weight of a female 30 days old, but its rate of growth was somewhat higher than that of a normal 30-day old female rat.

Chart 6 Shows the rate of growth of a female rat which was stunted from time of weaning until it was 314 days old. When the rat resumed growing, at an age at which growth has normally ceased, it weighed 72 grams, the average weight of a female 50 days old, but its rate of growth was slightly higher than that of a normal 50 day old rat.

tensive series of experiments in which the animals are stunted until a very late age before being placed under conditions suitable for growth. The rate of growth is not, however, a function of age, but of size. Every animal apparently has a certain normal size which it endeavors to reach in spite of vicissitudes during its early life. To what degree it is successful in this endeavor is probably dependent upon the extent of the injury inflicted upon it by its early experiences, and the favorableness of the external conditions during its period of growth.



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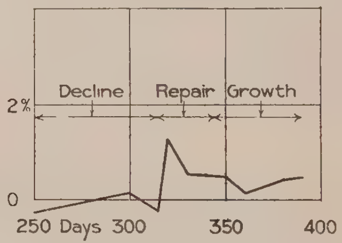

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Chart 7 Shows the rate of decline and repair, followed by late growth, for a male rat, at an age at which growth has normally ceased.

Chart 8 Shows the rate of decline and repair, followed by late growth, for a male rat, at an age at which growth has normally ceased.

While this method of measurement is interesting as emphasizing some of the similarities and dissimilarities in the rate of growth of different types of animals when studied by means of comparable curves, for ordinary laboratory work it is far inferior to the more commonly used method of determining merely the successive changes in weight, because even large variations in weight are entirely concealed. At the age of 260 days the rat whose rate of growth is shown in chart 4 weighed little more than one-half as much as the one whose rate of growth is shown in chart 3—a fact which these curves fail to emphasize. Moreover, the actual amount of weight regained by the rats whose curves of repair are shown in charts 7 and 8 was very much larger than these curves would indicate, because both were large rats and the percentage increase in weight is therefore much less striking than the absolute increase.

SUMMARY

1. Charts are given showing the rate of growth of albino rats under normal conditions, and after periods of stunting or of decline.
2. The curves for normal animals are very similar to comparable ones for other types of animals.
3. After prolonged periods of stunting rats are capable of growing at a rate normal for their size rather than for their age, showing that the rate of growth is a function of size rather than of age as has been commonly supposed.
4. Although this method of representing growth is interesting for comparative study, for ordinary laboratory work it is inferior to the usual method of plotting absolute increments, because even large variations in weight are thereby concealed.

RECONSTRUCTION OF THE NUCLEAR MASSES IN THE RHOMBENCEPHALON

A PRELIMINARY NOTE[1]

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Following Born's wax plate method, a reconstruction of the nuclear masses of the medulla and caudal portion of the pons has been made in order to gain further knowledge of the morphology of the various collections of gray matter. The reconstruction has been based on the serial sections of a human adult brain stem (no. 2627) in the neurological loan collection of the Anatomical Laboratory of the Johns Hopkins University. A magnification of 15 diameters was chosen as this enlargement practically coincides with that used by Miss Sabin in her reconstruction of the brain stem of the newborn babe and as it permitted the use of a plate of convenient thickness.

Realizing the possibility of error in such a reconstruction, attention has been paid to the verification of the three planes necessary for the correct piling of the individual plates. The major part of this control of the planes has been based on the external form of the brain stem but it was found also that considerable reliance could be placed on the comparative study of sagittal sections and of the limits of certain tegmental structures. In the main, entirely too much variation was found in the basilar architecture in different brain stems to permit of any accurate comparisons of this region.

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[1] The complete report of this reconstruction, with illustrations of the mode, by Mr. Max Brödel, will be published in the near future, as monograph No. 1911 by the Carnegie Institution of Washington.

Individual interpretation of the many nuclear masses has as far as possible been eliminated from the reconstruction. Most of the collections of nerve cells have been delimited under low magnification with later substantiation of the limits under higher powers. It has been felt that probably more correct ideas of the nuclear masses are given by their characteristic appearance under slight enlargement than by the identification of the limits of the area in which the characteristic nerve cells of the nucleus can be made out. Comparison of the findings by these two methods has shown the variation to be very slight.

In this reconstruction all the morphological characteristics of the various nuclei have been preserved as long as the preservation was technically possible. This more intimate anatomy of the nuclei varies undoubtedly in different brain stems but it has been thought of value to present this finer morphology of one brain stem as it is only by this means that the ultimate conception of the morphology of the nervous system can be advanced. The grosser form of each nuclear mass is, however, probably identical in all cerebro-spinal axes.

Different nuclear masses have been modelled on the two sides of this reconstruction. The left side shows only the individual collections of nerve cells which go to form the well-defined nuclei. The anterior motor column is also modelled on this side, clearly cut away from the central gray matter by the decussatio pyramidum. On this side, too, the nuclei underlying the fourth ventricle are given in their relation to each other. In contrast to this dissected left side of the model is the more solid and less open right side. Here an attempt has been made to show morphologically the transition of the indifferent gray matter about the central canal of the spinal cord into the formatio reticularis of the medulla. The external form of the formatio has been modelled on this side as has also the floor of the fourth ventricle. This presentation on the one side of the surface markings of the ventricular floor and on the other of the various nuclei which have surface representation, permits of accurate comparison of the ventricular anatomy with the underlying nuclear structures.

A brief statement regarding the gross morphology of the nuclear masses may not be amiss in this preliminary report. The more detailed and careful descriptions cannot be given here, but it is hoped that even these brief characterisations may have some worth.

The 'anterior horn' with its motor cells, beginning in the upper cervical region in this model, can be traced cephalad as a somewhat triangular column, marked by irregular longitudinal grooves and ledges. Superior to the cephalic limit of the pyramidal decussation, it is found to divide into two portions, parallel to each other and fusing finally in the ventrally projecting plates of the formatio reticularis. These plates of the formatio are to be distinguished by their freedom from medullated fibers and deeper staining qualities with carmine. The posterior sensory column of the spinal cord, in the region modelled, is characterised by its cap of substantia gelatinosa Rolandi. This constitutes an elongated column, oval on cross section and extending almost throughout the length of the model to end in the sensory enlargement of the chief nuclei of the nervus trigeminus.

The nucleus fasciculi gracilis appears as a narrow column which throughout its caudal one-half shows but very gradual enlargement. Then about its middle it suddenly widens laterally and maintains this increased lateral diameter until it terminates on the smooth nuclear plate in the lateral caudal portion of the fourth ventricle. On the other hand, the cuneate nuclei begin caudally merely as pyramidal elevations from the indifferent central gray matter. These nuclei rapidly increase their transverse, dorsolateral, diameters and appear on lateral view as broad, irregularly corrugated masses. The irregular markings are due to the projections from the main nuclear mass of the cells of Blumenau's nucleus: these cover in orderless cell columns the main nucleus, and the individual cell nests seen on cross section all prove to have definite connections with the chief nucleus.

As one inspects, in this reconstruction, the nuclei of the cranial nerves, it becomes quickly apparent that but a small part of each of the dorsal nuclei really lies superficially beneath the floor of the fourth ventricle. For other masses of gray matter are found dorsal to the majority of these cranial nuclei. The nucleus nervi hypoglossi (a rather regular cell column, pentagonal on cross section) actually presents superficially only its middle third—that part of the nucleus which shows a marked dorsal angle. Likewise, the nucleus alae cinereae—an irregular crescent of small nerve cells—becomes superficial beneath the ventricular floor only in its middle two-fifths and shows there a similar dorsal convexity. In like manner only the caudal portion of the oval collection of nerve cells forming the nucleus nervi abducentis is uncovered dorsally by other gray matter. The great median nucleus of the vestibular nerve of course lies superficial beneath the ventricular floor. This comprises the large median projection of a single diamond-shaped cell collection, usually divided into a spinal portion, a superior nucleus, and a lateral collection of motor cells (Deiter's nucleus). In this reconstruction the unity of the vestibular complex, first supported by Miss Sabin's work, has been assumed. The motor portion of the nucleus of the fifth nerve has of course representation in the lateral angle of the superior portion of the ventricle.

A large part of the ventricular floor is occupied by masses of gray matter which have no direct connection with the cranial nerves. Lateral and cephalic to the hypoglossal nucleus is the nucleus intercalatus which begins caudally as a sheet of cells lateral to the twelfth nucleus, increases to a maximum at the cephalic end of that nucleus, and is capped cephalad by an elongated truncated cone. A similar superficial cell collection is that of the nucleus incertus, which as a broad and thin sheet of cells sweeps cephalad in a gentle lateral curvature from the region of the nucleus abducentis. Mesial to the nucleus intercalatus is the cylindrical cell column known as the nucleus funiculi teretis.

Of the other tegmental nuclear masses dealt with in this reconstruction, the nucleus of the seventh nerve is probably most important. This is pear-shaped, with the neck of the pear extending toward the midbrain. It is irregularly grooved on its exterior, in a way suggesting its division into the component parts made out by Van Gehuchten. Caudal to this is the slender cell chain, showing three dilatations and a rather long intermission, comprising the nucleus ambiguus. And cephalic to the nucleus of the facial nerve is the double cell column of the superior olive, which extends cephalad and medially in parallel plates. The nuclear material, lying lateral to the tractus solitarius and first described by Mellus, has been reconstructed. This nucleus of the tractus solitarius forms a small irregular column, which expands considerably in its cephalic pole as it lies upon the ventromesial surface of the vestibular complex. Lying in the ventrolateral angle of the medullary tegmentum is the nucleus lateralis: this is a very bizarre column with cell spurs and projections which curve over the dorsal surface of the inferior olive and about the adjacent substantia gelatinosa Rolandi.

Placed in the wall of the lateral recess of the fourth ventricle and upon the corpus restiforme is the cochlear nucleus. When modelled, this appears as a continuous cell collection, with a large triangular ventral mass (the ventral nucleus), which is continued dorsally in a rounded projection (the dorsal nucleus). There is some morphological differentiation here into two nuclei, but no separation of the two portions is really justified.

The masses of gray matter lying in the basilar portion of the caudal part of the brain stem should be considered merely as two systems—the pontine and the inferior olivary. To the former complex belong the nuclei pontis, the nucleus arciformis, and the corpus ponto-bulbare (Essick). The latter cell group is composed of the nucleus olivaris inferior, the nucleus olivaris accessorius dorsalis and the nucleus olivaris accessorius medialis.

In this reconstruction the arcuate nuclei show considerable variation on the two sides. In general, however, they may be described as narrow cell plates which begin at about the level of the caudal pole of the oliva and extend cephalad with occasional intermissions to fuse with the nuclei pontis. As they near the pons the cell plates extend around mesially upon the anterior fissure and finally merge across the raphe before entering the pontine nuclei. They should be regarded merely as mesial caudal elongations of the cells of the pons. The nuclei pontis, themselves, constitute irregular cell collections which are considerably broken up by transversely coursing fiber bundles. Their external form is very ragged, consisting of nuclear spurs between the emergent fibers. The inferior portion of the pontine nuclei enlarges in all directions as one examines it from the caudal aspect. From the lateral portion of the pontine nuclei a cell chain can be traced caudally and dorsally to the edge of the fourth ventricle in the region of the median vestibular nucleus. This irregular column which curves around mesial to the cochlear nucleus constitutes the corpus ponto-bulbare, along which course the embryonic cells from the Rauten lippe of His to form the nuclei pontis.

The nucleus olivaris inferior is usually described as a hollow shell with wrinkled surfaces. In this reconstruction from the adult, the olive exhibits a rather long cephalo-caudal diameter as opposed to the other diameters, the whole giving the appearance as if the cephalic portion had been rotated upon the caudal. On the dorsal surface, three main fissures, as in Sabin's reconstruction, are made out, dividing the surface into four lobes, of which the cephalic overhangs (i.e., lies dorsal to) the other three. The main fissures extend around the lateral surface, passing caudally, ventrally and laterally, to terminate superficially upon the ventral surface near the hilum. This continuation of the main furrows upon the three surfaces permits of the tracing of the four dorsal lobes upon all of the three leaves constituting the olive. The mesial accessory olive is an extensive curving plate of cells, consisting of a main, quite broad and thin mass and several accessory cell collections. The dorsal accessory olive is a rectangular plate with a mild dorsal concavity, lying about the middle of the dorsal leaf of the olive.

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